Cornell University Library

BOUGHT WITH THE INCOME
FROM THE
SAGE ENDOWMENT FUND
THE GIFT OF
Henry W. Sage
1891

A.147524 28/5/1901

8441

arV11656 Cornell University Library

The romance of the heavens.

3 1924 031 323 839

olin,anx

Cornell University Library

The original of this book is in
the Cornell University Library.

There are no known copyright restrictions in
the United States on the use of the text.

http://www.archive.org/details/cu31924031323839

THE ROMANCE OF THE HEAVENS

THE
ROMANCE OF THE HEAVENS

BY

A. W. BICKERTON

Professor of Chemistry, Canterbury College, Christchurch
New Zealand University

AUTHOR OF "THE ROMANCE OF THE EARTH," ETC.

> **"The whole difficulty of Philosophy seems to me to lie in investigating the forces of Nature from the phenomena of motion, and in demonstrating that from these forces other phenomena will ensue."**—*Newton.*

LONDON
SWAN SONNENSCHEIN & CO., LIM.,
PATERNOSTER SQUARE
1901

PREFACE

A THEORY that finds Astronomy a chaos of facts and converts it into a classified system; that finds no generally accepted explanation of the genesis of a single celestial body or system and leaves none untold; that also shows the mechanism by which the Cosmos renews itself and gives probability to the belief that it is infinite and immortal, obviously trenches upon ground not commonly trodden. Such a theory must be of so comprehensive a character that it cannot be supposed that a small work like the present exhausts the subject. Any one of its four main divisions, if fully treated, would require a volume; as would the mathematical problems involved. On the other hand the present volume, although not strictly "popular," is such that, with careful reading, any person with a good school knowledge of experimental science should be able to follow the argument. In fact, so obvious are the main ideas, that, as deduction carries one from simple celestial bodies, past complex cosmic systems, to still more complex systems, one feels the mechanism of cosmic evolution to be the car of an intellectual mountain motor. And so easily is one carried past phenomenon after phenomenon to the loftiest pinnacle of human thought, that it is only by the variety of the scene, and the expansive width of the prospect that one realises the elevation to which one has been taken.

Readers of my former papers will see that the term "universes" so often occurring in them, has in this volume been replaced by "cosmic systems." This was done, because, as both Lord Kelvin and Lord Rayleigh independently pointed out to me, the term "universes" would be liable to be misunderstood.

CONTENTS.

CHAPTER PAGE

I. PARTIAL IMPACT, 9

II. TEMPORARY STARS, . 31

III. VARIABLE STARS, 49

IV. DOUBLE STARS, 65

V. SELECTIVE MOLECULAR ESCAPE, 80

VI. PLANETARY NEBULÆ, 91

VII. STAR CLUSTERS, 101

VIII. THE SOLAR SYSTEM, . 117

IX. THE ORIGIN OF THE SOLAR SYSTEM, 127

X. METEORIC PHENOMENA, 140

XI. THE VISIBLE UNIVERSE, 159

XII. NEBULÆ, 180

XIII. AN IMMORTAL COSMOS, 199

XIV. DEMONSTRATION OF THE THEORY, 213

XV. SYNOPTIC STATEMENT, 240

INDEX 277

CHAPTER I

PARTIAL IMPACT

CELESTIAL PHENOMENA — VARIATION OF SPLENDOUR — INSIGNIFICANT SIZE OF THE EARTH. CELESTIAL EVOLUTION SUGGESTED—A THEORY BLENDING PHILOSOPHY WITH SCIENCE—OTHER THEORIES UNSATISFACTORY. COMPREHENSIVE SCOPE OF THE INQUIRY. ASTRO-PHYSICS—HEAT A MODE OF MOTION—ITS TWO KINDS — RADIANT ENERGY—THEORY OF HEAT AND MATTER — CONVERSION OF MOTION OF MASS INTO HEAT — HEAT RESULTS FROM IMPACTS—HIGH TEMPERATURES AND HIGH VELOCITIES—CRITICAL VELOCITIES. POSSIBILITIES OF STELLAR COLLISION — DIRECT COLLISIONS IMPROBABLE. THREE PHENOMENA ASSOCIATED WITH PARTIAL IMPACT—A THIRD BODY FORMED — HIGH TEMPERATURE EVOLVED — INSTABILITY OF THE NEW BODY.

INTRODUCTORY

The phenomena of the heavens have ever been matters of interest to historic man, and doubtless his pre-historic ancestors also pondered over these mysteries. They could not fail to note the rising and setting of the sun the moon, and the stars; nor could they help observing the phases of the moon and her periodic change of place with regard to the sun, and the similarity of her phases with her similar relative positions. They would detect that the winter aspect of stellar distribution differed from its summer aspect. The splendid genius of the paleolithic artist, who, as proved by the remnants of the past, could sketch with such spirited fidelity the giant elk and hairy elephant, would have forced upon his trained eye the permanency of the pattern in the stars of the celestial vault, and amidst that permanency he would detect the planets by their erratic movements.

As he noticed the permanence of the varied glory of the stars, he would perceive in those wandering lights not merely difference in splendour, but that this splendour also varied periodically as did their place amongst the stars. The observant eye of the artist would note not merely the contrast of dark and gloomy Saturn with brilliant Venus, but would also observe the glowing effulgence of Venus at quadrature compared to her aspect at other times. But if none of these fixed and changing marvels attracted him, the most stolid eye would be delighted, when stretching from zenith to horizon, the magnificent plume of some gigantic comet swept with majestic grace across the whole expanse of the heavens. And as he watched these many marvels, his questioning mind would ask, as we continue to inquire, Why? and Whence?

Both to primitive and to early historic men alike, the vast earth upon which they lived would occupy in their thoughts the place of premier importance, so they would answer the question Why? by assuming that all the celestial glories were but ministering lights for man's convenience and joy.

Not so can we now regard them. A speck of cosmic dust, a mote in space, an insignificant member of a solar system resembling hundreds of millions of systems in our single universe—such is the astronomer's verdict as to the cosmic importance of our world. And we members of the human family, what are we compared in size to a mountain range? And what is the mountain range relative to the earth, the vast earth that it costs us months to circumnavigate? Yet a human being, with his thinking power, is marvellous. And marvellous is any animal, any plant. A leaf is a laboratory built up of wonders, of cells whose complexity is only now beginning to be unfolded to us. Then every part of every cell is made up of myriads of molecules, each molecule a regiment of atoms ; whilst the spectroscope reveals to us the incredible miracle of the complexity of an atom. So that accompanying the loss of our sense of self-importance comes so deep a knowledge of miracles of structure, that a reverential awe equally impresses us whether we examine the complexities of the inconceivably minute or the immensities of cosmic extension, and the mystery and the sublimity of our own existence only grows the greater.

But whilst the marvellous structure and gigantic dimensions of cosmic bodies and systems are revealed to us in their complex grandeur, we hear little that we can accept concerning their genesis. Much indeed have astronomers made known to us of their exquisite order, but little have they instructed us in the mechanism of their evolution.

This attempt to fill this want, to describe scientifically, yet in simple language, a generalisation explaining the evolution of stellar bodies and systems, apparently succeeds in carrying the principle of evolution beyond a mere planet or even the solar system, and shows that it is a universal law controlling the cosmos. The theory shows not merely the mode of the genesis of the universe in detail and as a whole, but it also points out the possibility of the immortality of the cosmos, thus solving the problem which has been the great quest of the thinker of all times, and blending philosophic thought with scientific observation.

At a time when the once accepted theories of the origin of the Solar System have passed out of common acknowledgement, this generalisation gives an account of the genesis not merely of the order, but also of the apparent irregularities of the Solar System, and for the first time in the history of Science offers an intelligible account of the evolution of the galactic system, consisting of the Milky Way and the polar caps of nebulæ, together commonly known as the visible Universe; and this account of its origin is so consonant with its complex structure, with its extraordinary contrasts and its definite irregularities, that when understood, scepticism seems almost impossible.

The correlation involves general thermo-dynamics, the dynamical theory of gases, the doctrines of the indestructability of matter and energy, and it also shows the great cosmic importance of the diversity of the atomic weights of the different elements. It makes use also of such recent science that a few years ago the conception could not be fully worked out, and had to wait for facts since discovered. Many of its results are based upon and strengthened by the latest observations of the telescope and the spectroscope, by photo-telescopy and spectroscopy. It uses such recondite phenomena as Crooke's experiments in radiant matter. It was incomplete until the discovery of the five monatomic non-combining gases recently found in the atmosphere by Lord Rayleigh and Professor Ramsay; and it blends all these facts and observations into a perfect whole, there being apparently not a single phenomenon that does not fall naturally into its place, nor one observation in opposition to its teaching. Every portion of the subject has been tested by graphics, and much of it confirmed by ordinary analytical mathematics. A perusal of the following chapters will show that although so far-reaching, the conception is one of comparative simplicity and flows naturally as deductions from the accepted laws of matter and energy. In fact the whole statement is but the application of chemistry and physics to celestial phenomena.

ASTRO-PHYSICS.

A skilful smith will take a nail rod, and hammer it until it becomes white hot ; and when an emery wheel revolves against a saw in the process of sharpening, a shower of sparks flies off from the edge of the disc ; in the same way when the break is put heavily on a rapidly moving train, sparks issue from between the rubbing surfaces. In all these cases we have heat manifested or produced by the partial stoppage of the motion of mass, and an immense number of experiments have at length demonstrated that heat is a mode of motion. It is accepted in fact that heat is the independent vibratory motion of the ultimate particles of matter. The mode of motion we describe as heat may be of two kinds. It may be an internal quivering of the atom or molecule itself, or it may be the independent motion of the atom or molecule in space as a whole.

Thus, to illustrate, if we have a spherical sheepbell and throw it against a wall, it bounds back again and rings as it comes towards us. In this act of coming towards us it has a motion as a whole, and at the same time it has an internal vibration manifested as sound.

This internal quivering usually dies down soon after the encounter; and the bell ceases to be audible. When there is a similar internal quivering motion in atoms, they give off radiant energy of definite rates of vibration, but in the case of solids and liquids the molecules are so close together that practically there is but little interval between the encounters, and consequently in the case of solids and liquids the heat motion is continuously of both kinds. When the vibratory phenomenon occurs inside a Crookes' tube in which there are but very few molecules, the molecules seldom strike one another, and the motion is very largely in free space. The molecules first vibrate when they strike the negative pole, and again vibrate on striking the opposite end of the tube. In the interval between the impacts they are moving freely but invisibly in space; and apparently their motion produces no radiation or motion of the ether; but when they strike the surface of the tube, the vibration produced by the impact gives out that peculiar radiation that is associated with the phenomenon of Röngten Rays.

In connection with the Theory of Constructive Impact, the properties of the ultimate particles of matter and the motion of molecules in free space will form a very large part of the subject, and therefore we must devote some time to the consideration of the atomic constitution of matter.

The spectroscope, we have said, reveals to us the complexity of atomic matter. As we examine its lovely chromatic ribbon we are reading atomic songs. The notes are too refined for the ear, the vibrations too small, so we use the eye, and it is the music of colour we perceive. Our eyesight, however, is too gross for much of this atomic music. The photographic plate is sensitive to many of these more minute vibrations, and there are substances exhibiting the property of fluorescence that accept the same minute vibrations and transmute them into such as are visible. In addition to this vibratory motion every atom is a storehouse of complex forces; though atoms are so minute that were an orange magnified to the size of the earth, the atoms of the orange would range from shot to shell in dimension. There are millions upon millions of atoms in a drop of water.

Of these complex singing atoms the earth is built. Mostly the atoms are locked together in attractive affinities that exist for ages. Sometimes they are changing partners at the rate of the quickest of Scotch reels a million times multiplied, but locked or free, they are always vibrating. Not all the ingenuity of man, not all his most refined machinery, can cause a single atom to come to rest. Cailletet and Pictet have produced such cold that the motion of the atoms has been greatly reduced ; and the liquifaction of hydrogen has enabled us to obtain a still further reduction of the vibrations of the ultimate particles of matter, but even with all these agents the irrepressible atom still moves.

In a gas or vapour the particles are free, and fly about, knocking one another and the sides of the vessel containing them, thus exercising pressures that may be enormous. They force the pistons of giant engines to do the work of thousands of horses ; rend immense rocks in dynamite explosions ; and send the molten lava of the volcano high into the air. Then we may reduce the motion (cool and condense the vapour we say), and the molecules cling together by their mutual attraction; but still they roll so freely over one another, and slip about so easily, that the liquid produced by the condensation will find its level. Yet even in the liquid there is still a great unrest. Drop a particle of soluble crimson pigment into a tall jar of liquid, leave it a few days, and the restless atoms carry the colour, particle by particle, up the jar until the whole is tinted. Again reduce the speed of the molecules by further cooling, and another attraction sets in; the molecules as it were clasp hands and are locked into a solid by the force we call cohesion. Definite parts of one molecules attract definite parts of others, and lovely forms are produced.

The exquisite stellate snowflake, the feathered fern-like frost upon the window pane, and the marvellous structure that salicine, soda, and many other crystals exhibit under the polarising microscope are examples of this force of cohesion.

On the earth we have the molecules in all three states, tight locked in the granite rock and the steel girder bridge, sliding freely over each other in the waters of the great oceans, and free to move in the atmosphere in the form of vapour and gas.

This vibrating motion or heat that changes solids into liquids and a liquid into a gas is a form of an entity called energy, whilst the atoms in their varied forms are called matter.

These two indestructible entities: matter and energy, are each capable of existing in many forms, but the cosmic sum total of either is apparently incapable of being lessened or increased.

There is another entity called ether, that is possibly made up of electricity in a medium. Ether appears to fill all space, and is the carrier of radiant energy.

Energy is always associated with matter or ether and we have no conception of energy but through the interposition of matter or ether; nevertheless, energy may pass from one body of matter or ether into other bodies.

Heat is only one of the many forms of energy. The motion of a projectile is another, and when a projectile is suddenly brought to rest the energy that it possessed as motion of mass becomes largely converted into motion of its particles, or what we call heat.

If a body be perfectly elastic, it is distorted by an impact, but recovers its shape directly afterwards, and in doing so bounds back again. In this case, no heat is produced. If, instead of being elastic, the mass impacting be similar to lead, the whole form may be changed by the collision. The motion of the mass as a whole in this case disappears, and the constituent atoms quiver with the friction of the atoms sliding over one another. So rapid may be their motion that the internal vibrations may effect the ether and produce a flash of light. It is in this way that motion of mass changes into that motion of the particles that we call heat.

Now the energy involved in the motion of a ton weight moving at a certain velocity is exactly the same whether the ton weight be a single body or made up of bullets or shot. It is quite easy to carry the conception still further down until we imagine that the ton weight consists of the separate ultimate particles of matter, all moving together in the same direction, but without independent internal motion.

Should an impact occur, this motion that was formerly parallel becomes indeterminate, and disregarding the internal vibration of the molecules, we are justified in assuming that the irregular motion of the molecules after the impact will be of the same velocity as the motion of the mass before the impact, provided of course, that the *whole* of the motion of the mass is converted into the indeterminate motion of the molecules.

There is a definite general velocity in each different kind of molecule that represents its temperature. The higher the temperature the faster the molecules move. If they move at twice the speed the energy is four times as great, and the temperature is four times as high. The idea of one thing being hotter than another is simple, and it is possible to say that it is twice as hot, but on our thermometers if we say that the temperature of a thing is twice as hot if the temperature is 200 degrees, instead of one hundred degrees, it is not true, because the zero of our thermometers is not the zero of true temperature. The Centigrade zero is the freezing point of water, but there is heat, we know in a snowball. It is said that an ingenuous student once asked his professor how many snowballs would be needed to cause a kettle to boil. The answer is easy enough, for if the kettle were filled with liquid hydrogen, or even with liquid carbonic acid, and if the snow ball were big enough, it would easily cause either of these liquid substances to boil, and the snowball would be very much colder after the operation.

But there is a temperature below which we believe it is actually impossible to go, and this point is 273 degrees below the zero on the Centigrade scale. This temperature we call the absolute zero. At this temperature the motion of atoms and molecules would cease. If we make this point the zero of our scale, than 200 degrees absolute would be twice as hot as 100 absolute.

Now 200 degrees 'absolute is probably about the temperature of the outer regions of our atmosphere, and there the velocity of molecules is such that hydrogen would move at about a mile a second and oxygen at a quarter of a mile a second. Therefore, were oxygen moving at the rate of a mile a second, the temperature or energy would be as the square of the velocity. So the temperature of the oxygen would be sixteen times as great as it is at the surface of the atmosphere; in other words oxygen moving at the rate of a mile a second would be 3200 degrees absolute, or taking off 273 degrees to change it into the Centigrade scale, it would be 2927 degrees Centigrade.

Now it is perfectly certain that in an impact of cosmic bodies, a speed of one hundred miles a second is comparatively a low velocity. That is to say that the temperature of hydrogen would be two hundred times 100^2, or 2,000,000 degrees of absolute temperature, and oxygen would be sixteen times as hot as the hydrogen, whilst the heavier metals would be heated in proportion to their atomic weights. From this it will be easily seen that an impact occurring between bodies travelling at the rate of one hundred miles per second would give temperatures, dependent on chemical constitution, that would range above 100,000,000 degrees. Such then are the temperatures that we shall have to deal with in the investigation—temperatures from a thousand to hundreds of thousands of times as great as the most fervent heat of our hottest furnaces.

Our personal experience of motion only extends to small velocities. We are appalled at the falling avalanche; we know well the velocity of an express train and the disastrous results of a collision on the railway. The sun moves at the comparatively low cosmic velocity of four miles a second, and were the colliding trains moving at this velocity the energy involved in the collision would be fifty thousand times as great as it is at sixty miles an hour. The Earth moves forward in its orbit at about a velocity of twenty miles a second, that is with an energy twenty five times as great as if it had only the velocity of the sun. If we could shoot a projectile from the surface of the earth at a velocity equal to the velocity of the earth in space, it would leave the sphere of the earth's attraction and never come back again. In fact there is a velocity connected with each cosmic body that just permits a body to be shot away from it so that it will not return, and this velocity is called the critical velocity. This is a conception of extreme importance to the theory of Constructive Impact. The critical velocity as regards the earth is seven miles a second, but a projectile shot from the earth at a velocity of seven miles a second, although it would leave the earth, would not leave the solar system. The energy would require to be many times as great. A body so shot from the earth would acquire an orbital motion connected with the sun, yet would pass through the very same spot from which it was shot from the earth in its annual revolution around the sun. Its year, however, would not correspond with the year of the earth, but would be near it in length of duration.

For a body to be shot away entirely from the surface of the sun, it would require to have a velocity of 378 miles a second, and this consequently is the velocity that a small planetary body, placed at the extreme limit of the sun's gravitating power would acquire were it to fall into the sun.

Were two suns similar to our own to fall together by mutual gravitation, the distance that each would have to fall would only be half that of a small body falling to the sun, because each would travel towards the other through half the separating distance, and if they remained spheres when the surfaces touched each other, only half the energy would be developed in the velocity, compared with what would be developed if the centre of one of the masses, instead of being at radius distance, were on the surface of the other sun. Each of these agents would halve the energy and consequently the total energy would be just a quarter of the greatest possible for a particle, or equivalent to the energy involved for half the velocity, that is a little less than 200 miles a second.

It is in the highest degree improbable that any particular pair of suns should come into collision, their proper motion in space preventing it. Should, however, any pair of equal bodies collide, it is very much more probable that the collision shall be of a grazing character rather than that the bodies should approach one another centre to centre and collide directly. The case resembles the respective probabilities of a blind rifleman striking the centre of the bull's eye, hitting the target anywhere, or shooting hopelessly wide of the mark altogether.

But in these cosmic collisions the agency of attraction comes into play, and the pull of the one body upon the other considerably increases the chance of a collision. Now a collision that is thus produced by deflection cannot under any possible circumstances be directly centre to centre; the conditions of orbital motion render it impossible. Thus then, between fairly equal stars or dead suns the probability of a grazing impact is very much greater than the chances of a complete collision centre to centre, whilst the study of the modes of grazing impact introduces such an immense number of possibilities, that its detailed study is well worthy of being regarded as a new cosmic philosophy.

PARTIAL IMPACT.

In partial impact, in the first place, if the graze be slight, the two bodies will not be stopped in their way. The two parts that graze will mutually destroy each other's motion of mass, and standing in each other's way, will be cut from the main masses of the colliding bodies. and will approximately come to rest. Such an impact as this has been called a " partial impact."

A partial or grazing impact of two suns will produce three phenomena. In the first place, as we have seen, a slight graze will not stop the main portions of the colliding stars, nor appreciably affect their velocities. The grazing parts will simply be sheared off; will largely destroy each other's momentum and convert this energy of mass-motion into heat; and by the coalescence of the sheared parts a third body will be produced between the two original bodies.

Secondly, the temperature of the third body will not depend upon the amount of the shear but simply on the velocity transmuted into heat, and on the chemical composition of the mass; that is to say a hundredth part cut off will be as hot as a tenth.

Thirdly, the stability of the coalesced body *will* depend on the amount of the graze. If the graze be small, the temperature, that is the molecular velocity, will be the same as with a complete collision; but the attractive power of the third body will depend on the mass, and obviously will be less than if the two stars had coalesced completely. The attraction may easily be so small that each molecule as it reaches the surface of the newly formed third body will start on a journey never to return, being endowed with a velocity of greater than the critical velocity required to escape the mass. The sheared-off mass consequently expands with a great temporary increase of light, but after a time the nebula produced will become so rarefied as to give but little light, because the molecular encounters will be increasingly fewer.

It will in fact expand into a hollow shell of gas, or become as it is called, a "planetary nebula," and finally, it will often dissipate into space. Hence there is produced suddenly, a very brilliant body that loses its light, not because it has cooled, but because it was too hot to hold together.

These three phenomena are involved in every case of partial impact, but scores of new conditions come crowding on that complicate the results. These will be studied in detail in future chapters under their respective headings.

CHAPTER II

TEMPORARY STARS

TEMPORARY STARS — THEIR SUDDEN APPEARANCE, EXTREME BRILLIANCY AND BRIEF INTENSITY—ANCIENT AND MODERN RECORDS—TEMPORARY STARS ASSOCIATED WITH LUMINOUS GASES AND INCANDESCENT SOLIDS. HYPOTHESIS OF STELLAR COLLISION—DEFECTS OF OTHER HYPOTHESES. MARVELLOUS STORY OF NOVA AURIGÆ. PROOF THAT DEAD SUNS EXIST—PROBABILITY OF THEIR COLLISION. PENETRATING POWER OF PROJECTILES. HYPOTHETICAL RESULTS OF STELLAR COLLISION—TRANSFORMATION OF MASS-MOTION INTO MOLECULAR MOTION—INTENSE HEAT—GASIFICATION—EXPANSION—ROTATION—DISSIPATION.

In November, 1572, Tycho Brahe, the Danish astronomer, was unspeakably astonished to behold a new star of extraordinary brilliancy in the constellation Cassiopeia. It must have appeared quite suddenly, for, Tycho Brahe tells us, he believed it was not visible an hour before he noticed it; and indeed coach-drivers and country people also observed it at the same time. When first seen it was very brilliant. It soon became more brilliant than Sirius; it rivalled Jupiter ; it was even brighter than Venus at quadrature, and it grew to be so bright it could be seen at noonday. The fact that it was fixed in space showed that it was at true stellar distance, and therefore it was the most brilliant body in the entire heavens. Probably it gave off over a hundred thousand times as much light as our sun. Then in a short time it began to diminish in intensity ; in a few months it was only a star of the second magnitude ; and in seventeen months the Pilgrim, as it was called, had faded away completely.

Kepler also describes a very similar star that lasted about a year.

These evanescent stars are recorded all through history both in China and Europe. The Chinese record gives us a long list of strange stars, many of which were doubtless true temporary stars. They record such phenomena in B.C. 134, in A.D. 173, and in 1011. On many occasions they have been observed in Europe. Possibly the most remarkable temporary star recorded was in B.C. 125, which was visible in the daytime and is said to have attracted the attention of Hipparchus, and led him to draw up a catalogue of the stars, which is the earliest on record. Other temporary stars are recorded in A.D. 389, and in the years 945 and 1264. In 1572 occurred the brilliant phenomenon described by Tycho Brahe.

Fully twenty such sudden appearances of stars are recorded, some within the last few years; but these later ones were not prominent objects, telescopes being needed to observe them properly. Yet so marvellously have photography and the spectroscope added to the power of the telescope, that these points of light have given us stellar information which the brilliant visitants of the past never afforded us.

The first star to which powerful modern astronomical instruments were applied was the new star in the Crown which appeared in 1866. The spectrum of this star, when examined, appeared to be continuous, with bright lines upon it, showing the presence of luminous gases, and incandescent solids, but much information as to its nature was not obtained.

It was the appearance of the new star in the Swan in the year 1877 that first directed my attention to the stupendous nature of these new stars, and to the fact that astromoners were entirely at a loss for a sufficient explanation to account for their extraordinary brilliancy and rapid disappearance; the current theories of the time being both inconsistent with the modern conception of energy, and utterly insufficient to account for their peculiarities. In casting about for an explanation of the almost unthinkable acquisition of heat necessary to account for such an extreme and evanescent luminosity, the possibility suggested itself that the phenomenon was due to a collision that had transformed the darkness of dead stars into the brilliancy of a new born sun.

All observations of temporary stars tell the same story of sudden appearance; temporary increase of brilliancy; rapid and generally complete disappearance, sometimes leaving a planetary nebula.

A new star is a giant sun that has been suddenly born; a body of surpassing brilliance and inconceivable size; appearing all at once in the universe, to fade away again in a few months.

It was quickly apparent, as already shown, that in the majority of cases such collisions would not involve the impact of the bodies as a whole, but would be generally of a grazing character, producing two wounded stars, and a third intensely heated unstable body. Flint and steel, as it were, had met one another, and struck off an inconceivably brilliant spark.

The stupendous velocity acquired by dense cosmic bodies falling towards one another, would suffice, in the generality of cases, to carry them through one another in a period of considerable less than an hour.

What other explanation than that just indicated can there be of such a stupendous event? Suggestions there are, startling in their insignificance: the sudden combustion of hydrogen in a dead sun; the bursting out of a volcano, or the plunging of a planet into a dead sun; the passage of a meteoric train through the atmosphere of a dead sun; the collision of meteoric swarms; the tidal disturbance of two dead suns passing near one another, and so on. Think of a bonfire or a volcano ten thousand times the size of our own sun! Suppose we even imagine such a mass of heated matter to be produced, how long would it take to cool? Our particle of cosmic dust—the Earth—probably took hundreds of thousands of years. Our sun has taken tens of millions, and will probably take more than ten million years longer to cool. Yet a body ten thousand times his brilliancy vanishes in a year!

How easy to imagine such a disappearance on the theory of partial impact? According to this theory the disappearance is not suggested as in the faintest degree to be due to cooling, but to be due to such stupendous heat and of so high a temperature that most of the molecules of the body are above the critical velocity, and thus they dissipate until finally they wander alone in space.

If the information available at the time of the development of this theory was not sufficient to demonstrate it in its entirety, such was not the case after the star Nova Aurigæ appeared in December, 1891. The history of this star is most interesting and extraordinary. Between December 8 and 10 a star made its appearance where no trace of a star had before existed. It was not there on the 8th, but was in evidence on the 10th, and there were two intervening days when clouds prevented observation; yet for many weeks after its actual appearance no eye perceived it. It was, however, writing its record on the plates of the photographer. It was first seen in February, 1892, by Mr. Anderson. He wrote an anonymous letter, asking if the star were not a new one. Such indeed it proved to be, and soon telescopes all over the world were scanning the face of the stranger. Step by step observation proved that its phenomena were of an amazing character. The star was found to be double, and its two parts were moving at a relative velocity of more than 700 miles a second. Then a third body was detected to be moving at the rate of some 23 miles a second. The character of this third body was long in doubt. At length it expanded into an undoubted and undeniable planetary nebula, and Professor Barnard of the Lick Observatory, by means of his magnificent telescope, succeeded in measuring its disc. The light of the combined bodies fluctuated greatly, but these fluctuations were not due to the nebula that produced the bright lines in the spectrum, but to solid matter. So greatly was scientific attention drawn to this star, that Mr. Alfred Taylor, F.R.A.S., himself examined the work of 85 observers, and stated that the material from which he abstracted his report would be equal in volume to that of an immense book. His summing up of this enormous mass of recorded observations was to the effect that there was no doubt that the new star consisted of three separate bodies. Since the finding of Nova Aurigæ several other stars have appeared, the spectra of which correspond very closely to it in character.

The suggestion made in this cosmic theory is that all temporary stars result from the grazing impact of stellar bodies, and in those cases where the temporary star has appeared where no star before existed, the colliding bodies were non-luminous or dead suns.

The variable star, Algol, demonstrates that there is such a thing as a dead sun, and over thirty years ago Dr. Johnstone Stoney suggested that they existed, while Sir Robert Ball believes that they are probably more numerous than the stars that give out light, or what we call fixed stars.

Collisions between suns will have their probability increased by their mutual gravitation, and when suns approach one another it is admitted generally by astronomers that a tidal action will distort the stars, dragging out portions egg-ways towards one another, and it would be these protruding parts that would tend to collide. It may be thought that there would not be energy enough to cut parts from the solid masses of the suns, but a few minutes' consideration will show that the energy available is absolutely millions of times greater than that necessary. It might also be thought that if the bodies grazed at all, a complete coalescence would ensue, due to their mutual attraction. A few more minutes' consideration will show, in the first place that not merely is a cosmic body easily cut, but that no coalescence will take place unless a comparatively large mass is struck from both.

I shall show later on, that when a third of the bodies are struck off, and the sheared-off masses coalesce, that the great additional attraction exercised by it upon the retreating bodies will in most cases cause a "whirling coalescence" of the bodies; but the assumption that we are making now, is that a small fraction, say a tenth or a fiftieth part, is struck off from each of the two bodies, the two small fragments coalescing to form a third body.

The penetrating power of projectiles from modern guns, and the colliding powers of express trains represent our terrestrial idea of impact, but we speak of these bodies moving at so many feet per second or miles an hour; but there is more than 27 million times the energy when moving a mile a second than when moving a foot a second, for the energy developed is in proportion to the square of the velocity, for since there are 5,280 feet in a mile, the square of this number is 27,878,400. In the case of an express train we speak of a velocity of sixty miles an hour, or a mile a minute. Compared with this velocity, that acquired by comparatively small suns of 100 miles a second gives us 60 squared, or 3,600, multiplied by 100 squared, or 36,000,000, so that an express train moving at the velocity of 100 miles a second would develop an energy 36 million times that involved in a speed of a mile a minute. We have also to take into consideration the relative masses of the train and the star in order to be able to estimate the shearing force available. Not only would these considerations show that the force available is enormously greater than is necessary to produce the shear, but it also indicates the amount of energy available in order to account for the temporary escape of the bodies from each other's gravitating attraction.

It is clearly demonstrable therefore, that, were two dead suns to strike off a small fraction from each other, the two colliding bodies, in a wounded condition, would pass on their way, because neither body would exercise a sufficient attraction to produce coalescence unless the graze was considerable. The phenomena of these wounded stars and this attraction will be debated in the chapters on variable and double stars respectively. For the present we are only considering the characteristics of the new body formed by the collision of the two stars and the combined influence of the three bodies upon the light of the complex spectrum produced.

A great increase in the complexity of the problem produced in such a case of impact would be introduced by the variety of chemical composition of the substances of which the temporary star is built up, for as we have already shown, if the star consisted of lead, it would be 207 times hotter than if it consisted of hydrogen. But, although there is this very great difference in the temperature resulting from the collision, there is no difference in the molecular velocity produced, assuming that the whole of the star be made up of a single chemical element. Thus with a star of lead or of hydrogen, the molecular motion that would be produced by the transformation of the motion of the stars into molecular motion in free space would be identical. Hence to lessen the complexity of the consideration of the subject of temporary stars, we will disregard the chemical composition until the time comes to deal with the subject under the heading of selective molecular escape in Chapter V.

Were I to enter mathematically into the problem, (which is not desirable in this preliminary statement) I could show that were two equal gaseous suns to fall upon one another, without having originally any proper motion, that the heat produced by the collision would be exactly sufficient to form a new body at the same temperature and of a diameter the sum of their diameters, the whole of the energy of their heat being transmuted into the energy of expansion; and I could also show that this condition would be one in which the molecules would be in equilibrium. In other words the energy of the impact of two similar gaseous suns would just suffice to make a new mass of four times of volume of both, and this new sun would be in equilibrium when it was neither hotter nor colder than the two original suns. The impact of two suns consequently does not possess sufficient energy to transform a gaseous sun into a nebula, unless, like 1830 Groombridge, they had great original proper motion.

Let us suppose our two suns that grazed each another to be dark, hot-centered bodies. Let us suppose a tenth be cut from each; the shear will not stop them, their acquired speed is so stupendous. The wounded suns go on; but the parts in each other's way must stop each other. A spinning motion will be present, but almost all that violent onward rush will be converted into motion of the particles, that is, into heat. Of course it is impossible to imagine the temperature produced; but, given the chemical composition and the velocity destroyed, what cannot be imagined as already shown can be calculated. The temperature may be a hundred million degrees Centigrade.

The intensely hot coalesced mass struck from the two suns is of course converted into gas. It is too hot to be stable, and the great mass expands at an incredible speed—generally the giant blazing globe would increase more than a score of millions of miles per day. There is no fancy in any of these statements, they are all plain matters of fact, deductions from the known laws of matter and energy; they assert exactly what would happen were a pair of suns to come into partial impact.

Therefore, if two dark suns did graze and cut off a tenth of each, it is absolutely certain a new star would appear in the universe. Calculation demonstrates that such graze occupies less than an hour. Singularly enough, with bodies of equal density, the size does not influence the time, because they get up commensurate speed. In this short time, then, a new sun is born. The tremendous expansion and increase in brilliancy sometimes last for days, then a new action sets in.

Temporary stars disappear, not by cooling, but because they are two hot to hold together. All have read of Jules Verne's Columboid, the wondrous-chambered shot that quitted the earth; and, such is human daring, I have known some ardent souls that long to make a similar journey. But not so can we visit the moon; we have neither the explosive nor the material to bear the strain. About a thousand times the energy of an ordinary shot would be needed to get up speed sufficient. As already stated, a shot hurled with a velocity of seven miles a second would leave the earth and not return. All the particles of the new star are moving with inconceivable speed—hundreds of miles a second. The velocity to allow of bodies escaping from suns of similar density is higher in proportion to the mass of the suns. So the less the mass of the new star, the less the speed required to escape from it.

Imagine that all the molecules are shots above the critical velocity; when any come to the surface they travel straight on and leave the mass. Hence, the mass expands in two ways: it expands by the tremendous pressure exercised by the molecules striking one another, and also expands because the molecules are always escaping and flying away. Their speed may be taken as a million miles an hour. After some months nothing remains but an immense hollow shell of gas aways expanding, in fact, one of Herschel's planetary nebulæ; only such a nebula as here described is not permanent—it continues to expand, and finally strews space with countless wandering molecules, some of which will in latter ages form material for the origination of new universes.

So, that in whatever other ways temporary stars may yet be explained, it is certain that a comparatively small partial impact of dead suns must produce a temporary star that will suddenly blaze forth, increase in brilliancy for a few days, then pass away by dissipation into space.

When we come to spectroscopic evidence there remains no room for doubt ; but this consideration will be more appropriate in our study of the two great dead suns flying from one another, each bearing the scars of conflict in lakes of fire hundreds of thousands of miles in diameter.

DIAGRAM SHOWING AN IMPACT OF TWO STARS OR DEAD SUNS, FORMING A TEMPORARY AND TWO VARIABLE STARS.

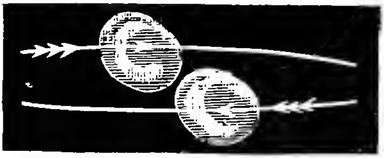


Fig. 1—Pair of stars distorted and coming into impact.

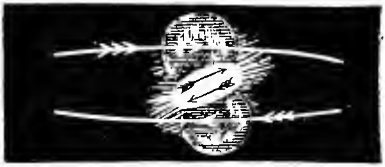


Fig. 2—Pair of stars in impact.

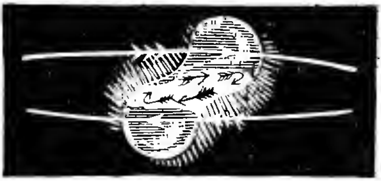


Fig. 3—Stars passing out of impact, and formation of third body.

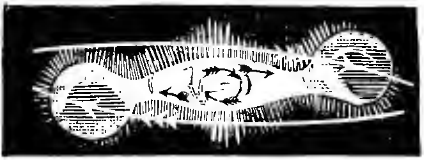


Fig. 4—Showing entanglement of matter in each body.

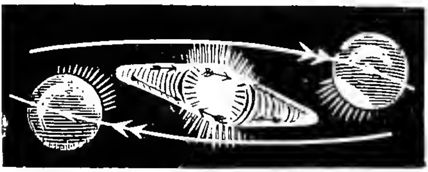


Fig. 5—Two variables and a temporary star.

CHAPTER III

VARIABLE STARS

MIRA, THE WONDERFUL STAR—ALTERNATELY DARK AND BRILLIANT. VARIABLE STARS DUE TO COLLISIONS—SPECTROSCOPIC INVESTIGATIONS—WHAT SHOULD, AND WHAT DOES HAPPEN—VARIABLE STARS FOUND IN CLOSELY RELATED PAIRS—ANTHELM'S STAR AND ITS COMPANION VARIABLE. VARIABLES ASSOCIATED WITH NEBULOSITY. AGENCIES AT WORK TO CONTINUE VARIABILITY. INFINITE VARIETY OF CONDITIONS AND PHENOMENA.

For just about four centuries astronomers have known of an extraordinary star in the constellation of the Whale—Mira, or the Wonderful, the older observers called it. Months elapse without sign of a star; then a faint light appears that grows stronger and stronger for about three months; for a few weeks it remains brilliant; then during the next three months it fades away again. This process is repeated year after year, the period being computed at 331 days 16 hrs. 7 min. There are many scores, perhaps hundreds, of stars that exhibit periodic fluctuations of intensity, though none are so remarkable as Mira.

How are we to explain the peculiarities of these stars?

Suppose we were to hang a policeman's lantern on a roasting-jack; it would flash and vanish, giving us an appearance similar to that presented by Mira. But another explanation is possible. Suppose we were to cut a large hole in the side of a tin can, and hang it over a lighted candle and let it spin, we should get the same result. Hence we see that a variable star may be a star with sides unequally illuminated presenting these sides alternately to opposite parts of the heavens. Or, there may be something that eclipses the star; we know that the short periodical eclipse of the Demon star (Algol) is due to the passage of a dead sun across its disc. The same is probably true of several other stars. Of these two ideas the revolving lantern theory best accounts for most of the variable stars.

Let us return to the two colliding dead suns we left receding from each other. Their partial impact has taken a slice from each and exposed the molten interior. As the two bodies fled from the flaming central mass, their enormous attractive force, and the lack of balance at each side of the colliding parts, would cause huge tongues of fire to follow each retreating orb, heating the struck part intensely. The heated centre would also be exposed, and well up as the body resumed its spherical form. The collision would also cause each of the two colliding suns to spin, and to present alternately a light and a dark face towards the same part of space. Thus easily is the mystery of variable stars explained. Deduction, therefore, from the well-known laws of matter and energy demonstrates that a partial collision of extinct suns produces three bodies: an immense flaming ball of fire, glowing and expanding at an enormous rate, and two cosmic bodies flying from each other at inconceivable velocities, each of these bodies revolving and showing its unequally heated surface. Presently, by mutual attraction, the velocity of the two bodies becomes so much reduced that the central expanding gaseous body overtakes them and envelopes them, and they become a double variable star within an immense planetary nebula.

A number of recent temporary stars have

been examined with the spectroscope, and although the evidence of the subject is somewhat conflicting, there being no theory to guide observers, yet the evidence on the whole is not contradictory, and fortunately, there are summaries by collectors of observations, one giving the result of the work of over eighty observers, and their summaries agree. The prismatic light of these celestial visitants is very extraordinary. Instead of the coloured lines that usually represent the notes of the vibrating atoms, the ribbon of light is crossed with broad, indistinct bands, and on either side of the centre of each of these bands is superimposed a line. By the rainbow tinted ribbon the stars tell us their story. How are we to read this stellar message?

When a beam of white light falls upon a prism it is bent to one side; but white light is made up of waves of many lengths, growing shorter, from red, through all the colours of the spectrum, to violet. Let us then imagine a beam of white light to consist of long waves striding onward and shorter waves running to keep up, so that all travel at the same rate. These waves meet the prism, and their directions are altered ; the shorter they are, the more they are deflected ; so they accompany each other no more ; they diverge, increasing the distance from each other until the bright beam of white light is coloured and fan shaped, and when it falls on a white screen, it is a long coloured streak. But the streak from the light of the stars is uneven, in fact, sometimes broken ; there is not a regular succession of waves of all lengths. The coloured streak of light is largely modified by the characteristic waves corresponding to the notes given out by the atoms. It is by the period of the waves that we recognise the atoms producing them. But in the spectra of new stars the notes are out of tune, and by notes being thrown out of tune we learn how the atom is being treated, and how it is behaving itself. The pitch of a tuning-fork alters if the fork is made to travel rapidly. If it be approaching us, the notes crowd upon one another, the waves shorten and the pitch rises. If travelling away, the waves lengthen out and the notes become flatter. In the same manner light waves are thrown out of tune by the travelling vibrating atom. If it be moving away, then the coloured line is displaced towards the red. If it be approaching us, then the displacement is towards the violet. When atoms are moving in all directions, then the waves are displaced both ways, and the line broadens out.

This is the reading of the beautiful cipher message from our new stars. Broad bands, indistinct at the edges, brighter in the middle, are produced by atoms travelling from us, sideways, and towards us, at speeds of hundreds upon hundreds of miles per second. In fact they are the message of the flaming, expanding orb that must result from the coalescence of the two fragments ; clearly it would give us just such bands. The two superimposed lines are telling us of a body travelling hundreds of miles a second towards us, and of another flying from us. The lines are on the band because the atoms forming the expanding nebula are travelling faster than the giant orbs themselves. One of the best determined measurements gave respectively three hundred, and four hundred and thirty miles a second, as the speed of the two constituents of Nova Aurigæ. Light and dark bands are due to another cause. A dark band is due to a bright light showing through a gas. A bright line is due to an incandescent gas. Hence, in partial impact, if the molten sea of the sheared sun shine through a hydrogen atmosphere, we may have a dark band. If the star presents the edge of the molten sea to us, it will be the gaseous atmosphere we shall see, and the lines will be bright. Obviously, whether going away or approaching us, the star may be in any position of rotation with regard to our earth, and in point of fact in either star the bright line should slowly fade and become dark and then bright again Here, then, is the full reading of the beautiful coloured cipher that came to us from that marvellous star. It would not be unfair to ask a student who knows nothing of impact to tell the kind of spectrum such a set of bodies would produce. There is but one correct answer; and, if a student cannot give it, he cannot read the spectrum. Is not this piece of evidence of impact most convincing? As we proceed proof becomes overwhelming. On the theory of partial impact variable stars are produced in pairs. Are any such to be found? I sought in vain for an assertion of the fact; then I plotted some of these stars, and on the pair of ten inch charts some were so close, that, in especial cases. I could not put a needle through one without destroying another. "Can this be chance?" I asked my mathematical fellow-worker in cosmic problems—Mr. Beverley, of Dunedin. Chance! He calculated and answered, "Certainly there is one chance in one hundred and sixty-two sextillions."

Since I have been in London, from Mr. J. E. Gore's list of suspected variable stars, I have selected from four hours of Right Ascension, such pairs of variables as seem distinctly to have been formed by the same collision. The following are their positions:

R.A.		Declination.		R.A.		Declination.	
h.	*m.*	°	′	*h.*	*m.*	°	′
3	38	23	59	6	33	6	9
3	39	23	34	6	35	6	27
4	14	19	31	6	43	13	33
4	14	19	14	6	47	13	20
5	1	8	48	7	8	22	28
5	3	8	54	7	9	22	43
5	28	4	55	7	26	3	32
5	29	4	56	7	27	3	27
6	31	18	33				
6	32	18	8				

The extraordinary coincidence that nine pairs of variable stars as close as these should occur within so small an area in proportion to the whole heavens,—about one-thirtieth of the celestial vault,—is obviously not the result of chance, and any sound theory of variable stars must account for such a fact.

The really great distance that these stars are from each other suggests that the condition of variability is one that lasts a considerable time, unless the proper motion of these stars is greater than that of the average star in space, yet the distances cannot be considered unreasonable. It would be of extreme interest for the astronomer to ascertain with accuracy the proper motions of these pairs of variable stars. The theory of impact suggests they are still increasing their distance.

Assuming that a variable star is situated at such a distance that its light would take ten years to travel to us and that the stars are increasing their visual distance from each other at the rate of ten miles a second, then in one hundred years the relative velocity would displace it 12′ of arc, as is shown in the following calculation :—

Light travelling at the velocity of 186,000 miles a second in ten years will travel 186,000

× 10 × (60 × 60 × 24 × 365). The stars travelling from each other at a velocity of ten miles a second, in one hundred years will travel 10 × 100 × (60 × 60 × 24 × 365). Dividing the former by latter gives us as 1 to 1860 as the relative distances travelled by the star and the light. Now a great circle of the celestial sphere is made up of 360 degrees, and this divided by the ratio of the radius to the distance travelled by the star amounts to slightly less than 12 minutes of arc.

If instead of ten miles they were separating at the rate of sixty miles a second, that is to say that each constituent of the pair had an apparent proper motion of 30 miles a second, then the distance they would travel in 100 years would be 1° 9″, that is an enormously greater distance than any quoted in the list.

But a still more remarkable demonstration occurs. Anthelm's temporary star of 1670, Nova Vulpeculæ, has near it a variable star. The respective positions being as follow:—R.A. 19h. 43m. 3s., N.P.D. 27° 2·6′; and R.A. 19h. 43m. 53s., N.P.D. 27° 0·8′. But there is in addition to this a smaller star very close to the position of Nova Vulpeculæ that is also suspected to be variable. If really a variable star, this would be an extraordinary confirmation of the theory. We should have a temporary star appearing 230 years ago and its two variables still near the position of the original impact and still variable; and yet not connected into a double star.

It is known to astronomers that variable stars are sometimes associated with nebulæ, as for instance Hind's variable T Tauri. Might not the nebulosity observed at the minimum of some of the long period variable stars be always present, but be overpowered at other times by the greater brilliancy of the body? We have absolute evidence that Nova Aurigæ did actually appear suddenly in the heavens; that the spectrum of Nova Aurigæ indicated two bodies flying from one another with enormous velocities; that there were such fluctuations of light that we should expect in the case of such revolving bodies, and that they were associated with luminous gas which, according to certain observers, did actually expand into a planetary nebula; and Professor Barnard succeeded in measuring its disc. In Sir C. E. Peek's detailed notes of variable stars frequent reference is also made to observed nebulosity.

Of course, a variable star, unequally heated, tends to lose its variability by conduction, convection, and all sorts of agencies. Still, I have shown that quite a number of counteracting agencies may possibly retard this equalisation of temperature for perhaps thousands of years. In consequence of this tendency to equality, I did not expect to find numerous variable stars in pairs; but in fact I found more than I expected. Therefore this indicates great permanence in the inequalities. I have already discussed this high probable permanency, and I will now attempt to describe some of the agencies that cause stars to retain their inequality of luminosity.

The equalisation of the temperature of any heated star may come about by conduction, by ordinary convection of liquids, by radiation, and also by the fact that there would be an enormous atmospheric disturbance connected with the highly heated scar that would be surging in a most extraordinary way about this huge molten lake of fire, as we see is the case even with a body of such equality of temperature as the sun It is curious to note that each of these agencies contains forces that are retarding the production of an equalisation of temperature.

Convection of heat is due to difference of density. The denser material tends to sink and the lighter to rise. Density itself may be due to high specific gravity of material or to lower temperature. It is almost certain that the centres of all dark surfaced bodies are hotter than the exterior. Hence if we cut one sixth from the surface of a star it will expose its heated interior. The wounded star of course quickly regains its sphericity and the molten interior now forms the surface. It is at an enormously higher temperature than the rest of the star, but it also consists of heavier molecules. The consequence is that convection will only go on until any difference of density due to the combined causes has died out, and when it has died out, the mass will still be hotter than in any other part of the star.

Conduction, too, is exceedingly slow in a liquid mass, and that the mass in this particular case is liquid is undoubted. Consequently, the attaining a common temperature by conduction must be exceedingly slow, for this scar of fire will often be as big as our sun.

In the case of radiation, the more highly heated metallic surfaces will naturally radiate faster than the others or we should get no variability in the star, but to attain equality of temperature by the difference in the rate of radiation would almost certainly take many thousands of years.

We have now to take into consideration the tremendous aëriel disturbance that is produced by this blazing lake of fire. We must examine the motion of the atmosphere of a rotating star with a lake of fire in the same way as we should study a trade wind, and take into consideration the fact that the vapour as it rises from the surface would form saline and metallic rain clouds in the higher regions of the atmosphere. The examination of these two agencies shows that a vast quantity of this material falls back again as molten rain almost exactly on the edge of the lake of fire. It would, however, gradually be carried farther and extend the size of the lake and would be a large factor in producing equality of temperature over the surface of the star.

Is there any evidence of the lessening of variability? It is overwhelming. Some stars are known to have been variable that are variable no more, and the variability of very many stars has diminished greatly. Besides the types described, there are all kinds of eccentric variables, as, of course, we should expect, for the field of possibilities of impact seems infinite.

Sir C. E. Peek's recorded observations of variable stars show a few cases of extreme irregularity both of the variable period and brilliancy, but since impact would result in two variable bodies of different periods of rotation, as well as a new star of ever decreasing brilliancy, and of almost certain nebulosity, the total light from a variable might be compounded of three elements. The existence of these three sources of light would alone account for irregularity, but in addition each of the wounded stars would be under the influence of a number of agencies all struggling to produce irregularity of variability. Thus it is probable that for some time after impact there would be two rotations. There would be a rotation of the shell or outer portion of the stars as a result of the impact; and there would have been almost certainly a rotation previous to the impact, and it might take many years for these rotations to blend completely. Then again, the large scar, the molten matter from the interior of the star, would overfill and sink back rythmically for an indefinite period.

Think of the amazing variety of conditions! The impacting bodies may be of the same, or of altogether different mass. They may have every variety of density; one may be dense, the other rare. They may be as dead as the moon, or as fiery as the sun. They may be of totally different chemical composition, or approximately the same. One may be a star cluster, another a nebula, or star clusters and nebulæ may collide with one another. Perchance a huge dead sun may recurrently plunge through a group of dead suns and give us the extraordinary Eta Argus. The bodies may have every variety of impact, from a meeting full face to face to the merest kiss. Is there any end to the list of possibilities? I think not, and hence, not to weary my readers, I will pass to the next chapter and try to describe the *modus operandi* by which that fiery kiss weds two giant orbs into a union that may last scores of millions of years.

CHAPTER IV

DOUBLE STARS.

DOUBLE STARS RESULT FROM IMPACT—VIEWS OF SIR ROBERT BALL AND PROCTOR—POSSIBILITIES OF STELLAR WEDDINGS—RECURRENT IMPACT RARE—COLLISIONS RESULTING IN PAIRS OF VARIABLES, BINARY SYSTEMS OR COALESCENCE—WHIRLING COALESCENCE. EVOLUTION OF AN ELLIPTICAL ORBIT. FACTS ABOUT DOUBLE STARS—THEIR VARIABILITY, COLOUR, CONNECTION WITH NEBULÆ AND POSITION IN THE MILKY WAY. OTHER WAYS OF WEDDING. CONSTRUCTIVE POWER OF PARTIAL IMPACT.

In 1877 the star appeared that sent my mind in quest of the stupendous agencies that must be working in the cosmos thus suddenly to produce a sun which in a year faded to a cloud of fire-mist. It did not cost an hour to learn what a scientific El Dorado I had struck upon. I saw that a graze was a force sufficient to cause burnt-out suns, Phœnix-like, to rise in wondrous glowing systems from the ashes of their dead past.

But not without long study were all the consequences of the graze revealed to me in the richness and the complexity, the power and the perfection of their action. So one must not wonder that the first thoughts of astronomers on these phenomena should be somewhat vague. The following extract from Sir Robert Ball's article on "Double Stars," published in the *Melbourne Argus*, will show that the idea of impact is gaining ground, although students of constructive collision will see by the extract how very imperfect the conception still remains even in the mind of so great an astronomer :—

He says—"Let us suppose that two of these globes, when bent on their voyages through immeasurable space, should happen in the course of events to cross each other's tracks and to be hurled each against the other in a mighty collision. No doubt, I freely admit that such incidents must be extremely infrequent in comparison with the number of globes for which such a disaster would be possible. But these objects exist in such myriads that ever and anon the chapter of accidents will suffice to bring some pair of globes into collision, though as regards any two particular globes the improbablity of their striking together would be quite as great as the improbability of the striking together of two specified rifle bullets in the air as they flew over a battle-field. But no one can deny that if, in the course of the battle, sufficient cartridges are discharged from both sides, this excessively unlikely thing to happen in the case of any particular pair of bullets may yet happen in the case of some pair. We have the best reasons for knowing that throughout the length and depth of the universe it has sometimes occurred that globes, hurrying along with a speed far swifter than that of any rifle bullet, perhaps, indeed, a hundred times as quickly, have thus been brought into collision. One effect of such a collision is amenable to calculation. There is not the slightest doubt that it must be accompanind with the evolution of a stupendous quantity of heat. In fact, it is known that if a globe moving with the velocity which this earth possesses, were to come into direct collision with an obstacle equally massive, the quantity of heat that should be produced by the impact would be so vast that each of these mighty globes would not only be heated red hot, but would actually be transferred into what we may describe as a fire cloud. Under ordinary circumstances the two stars would not come from exactly opposite directions, and thus strike each other directly; the blow must usually rather be described as a very serious graze. In such a case there would be an evolution of heat often sufficient to raise the whole globe from the extremely low temperature of space up to a state of vivid incandescence. After the collision the two objects would separate, each having conferred upon the other the glory of a brilliant star. The law of gravitation under all circumstances must assert itself. These two objects, deprived of a large part of their original motions by the collision, would assume movements of a new kind, the guiding power of which would be found in their mutual attraction. Under such circumstances each of the globes would revolve around the other, just in the same manner as a planet revolves around the sun. It may certainly be admitted that we have never up to the present actually been witnesses of the process by which a pair of glowing suns have been brought into such remarkable association. But it will hardly be doubted that such collisions must have occasionally produced the results above described when we note the fact that there are in the heavens thousands, I might doubtless say many thousands, of pairs of stars, each of which revolve around the other, just as if their origin had been that which we have described."

Sir Robert Ball refers to rifle bullets meeting. I have seen the photograph of a pair of bullets fused together by such actual collision. What Sir Robert says is very satisfactory as far as it goes, but he does not seem to realise the very slight effects of the graze upon the remainder of the orb. I have shown, by several lines of reasoning, that if the orbs were as hard as adamant their energy is a million million times in excess of the shearing force that is necessary to cut them; so that, wonderful as it may seem, the parts not impacting would not be greatly heated by the collision.

It will also be observed that Sir Robert Ball says such collisions have not been positively seen. But it has been shown that the birth of a new star almost certainly results from collision. He says nothing of the middle body produced; yet without this middle body the stars would collide again and again, ultimately coalescing.

When I spoke to Proctor on impact, he

readily admitted most of my reasoning as to what would result were a collision to occur, but was very emphatic as to the entire improbability of the event. But, at that time, photography had not revealed the amazing numbers of the stars, and the idea of dead suns was very vague; nor did he estimate the enormous deflecting power of the mutual attraction that suns would exert upon each other, thus tending to produce collision. Subsequently, in his Astronomy, he discusses the possibility of double stars being formed from collision, and points out this difficulty of recurrent impact. He admits the pair would be wedded; but he imagines that at each anniversary the gorgeous ceremony would be repeated. If so, each impact would necessarily use up some energy, until, instead of marriage celebrations, the occasion became a kind of battle royal, in which the blows would continue to grow quicker until the great orbs would coalesce into one huge nebulous bun-shaped sun.

Let us examine the agencies that render recurrent impact very rare. They are fully debated in my papers in the New Zealand Philosophical Transactions for 1880, under the headings "Double Stars" and "Agencies Tending to Alter the Eccentricity of Planetary Orbits." Much of the reasoning is very technical. However, we must consider some of these agencies.

We understand how a partial impact leaves three bodies—the vast flaming nebula and the two scarred suns. We see how the nebula expands, overtakes the suns, and envelopes them. It overtakes them because they quickly lose much of the velocity they had at impact. The suns lose this velocity partly as they gained it, by mutual attraction; but the great central nebula at first also exercised immense retarding influence, so they do not retreat with the velocity of their approach.

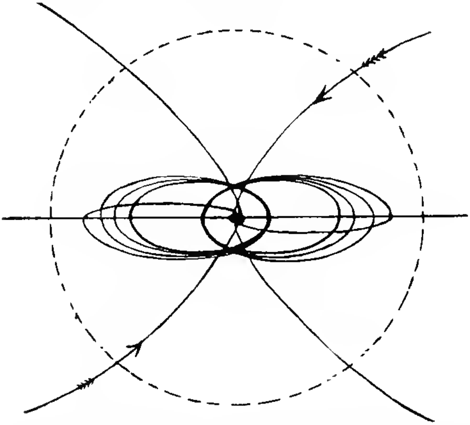
Suppose two equal suns to have lost a sixth each, then each sun weighs $\frac{5}{6}$ and the new body $\frac{2}{6}$, but as the new body is standing still in space, the time of the attraction is doubled; hence the total attractive energy after impact is $\frac{5}{6}+\frac{4}{6}=\frac{9}{6}=1\frac{1}{2}$, the original attractive energy. If there were $\frac{1}{3}$ cut off we should get three equal bodies, each $\frac{2}{3}$ the mass of the original bodies; the energy of the total new attraction is now double the original attraction and it is no longer a case of partial impact but one of whirling coalescence.

If the colliding pair had been swift suns before the attraction commenced, possessing a great independent motion like the star 1830 Groombridge, they would still lose some of this motion by the graze, but not enough to wed them. Probably, as a rule, dead suns move faster than brilliant ones, for, doubtless, the brilliancy of suns is partly kept up by impacts, which necessarily destroy some of their motion. But if such a slow sun as ours were very slightly to graze another such sun the pair would not escape; the extra attraction of the nebula of coalescence would wed them, and they would come rushing back towards each other. Why, then, would they not collide again?

This is the reason: the nebula that entrapped them would be outside their orbit on their return, and so, instead of being pulled back to collide, they would keep at distances of millions upon millions of miles from each other. What would happen to the earth were our sun to lose half its mass? It would speed away and its orbit would be immensely enlarged. So it is with double suns; the central nebula loses its mass, and so the pair enlarge their orbits and do not collide again. This is not the only agency which prevents recurrent impact, but it is the most important.

The accompanying diagram shows this agency. The hyperbolic orbit becomes a long ellipse.

Diagram showing the Formation of the Orbit of a Double Star.



The dotted circle represents the nebula expanded beyond aphelion distance.

The two continued hyperbolas represent the path of the two stars had there have been no collision. The collision occuring, the orbit becomes a long ellipse, that becomes of less eccentricity, because the nebula has expanded. (See also page 133).

When aphelion distance is reached, and it begins to fall back, the attraction is less; hence it does not fall so quickly and the ellipse becomes much less eccentric. At each approach amongst the meteoric matter left at impact aphelion distance is lessened and gradually the orbit becomes as it is in nature.

Thus we have seen partial impact produce the star that fades into star-mist and two rotating wonder stars. We have also seen how the central nebula weds the two stars, and then by dissipating prevents their impacting again. We have now to ascertain how the characteristics of double stars correspond with the conditions promulgated in these papers. Obviously, the orbits would be highly eccentric. The stars would often be associated with a nebula, and sometimes for thousands of years one or both would be variable; also, from the fact that the metallic interior would well up, and form a vast molten lake, they would tend to be coloured and have characteristic spectra.

Such are some of the deductions imperatively forced upon us if we consider that binary stars have been associated by impact. All are borne out by observation in a most remarkable manner.

Yet it was not easy to find most of the evidence ; I sought for more than two years before meeting any statement as to the variability of double stars. Then I came upon the work of the great Struve, and all at once obtained proof that variability is a remarkable characteristic of binaries. Struve had verified this as to twenty-five, and suspected forty more. Later observation shows the characteristic to be far from uncommon. Mr. J. E. Gore, in *Knowledge* September 1st, 1899, gives several examples, and in a recent letter to myself has pointed out four other cases. Colour and peculiar spectra are also characteristic. As to the association of nebulæ and double stars the following extracts from Herschel's "Outlines of Astronomy" will show how remarkable they are.

"The connection of nebulæ with double stars is in many instances extremely remarkable. Thus in R.A. 18h 7m 1s, N.P.D. 109° 56′, occurs an elliptic nebula having its longer axis about 50″ in which, symmetrically placed, and rather nearer the vertices than the foci of the ellipse, are the equal individuals of a double star, each of the 10th magnitude."

In a similar combination noticed by M. Struve (in R.A. 18h 25m, N.P.D. 25° 7′), the stars are unequal and situated precisely at the two extremities of the major axis. In R.A. 13h 47m 33s, N.P.D. 129° 9′, an oval nebula of 2′ in diameter, has very near its centre a close double star, the individuals of which, slightly unequal, and about the 9-10 magnititude, are not more than 2″ degrees asunder."

Herschel also says:—"Nebulæ of regular forms often stand in marked and symmetrical relation to stars both single and double. Thus we are occasionally presented with the beautiful and striking phenomenon of a sharp and brilliant star concentrically surrounded by a perfectly circular disc or atmosphere of faint light, in some cases dying away insensibly on all sides, in others almost suddenly terminated." He also mentions a case of the nucleus of Messier's 64th nebula being "strongly suspected to be a close double star," and states that many other instances might be cited. Doubtless modern astronomy would furnish other examples.

One has only to refer to any table of the elements of binary stars to see the high order of their eccentricity. Lastly, where stars are thick we should expect to find a high ratio of double stars, and such is the case ; nearly all the binary stars are confined to the Milky Way.

There are other ways besides impact by which suns may become associated. Whenever three cosmic bodies come near one another one of them has its velocity lessened. Thus, a comet approaching the sun may come near a planet, say, Jupiter ; and if its line of direction towards the sun causes it to be nearer Jupiter when it has passed than when it was approaching him, the comet will lose more velocity than it gains, and travel more slowly. Hence it may not have enough speed to get away from the sun again, and will thus become orbitally connected. Such occurrences would happen rarely with suns, but must have produced some binaries. The acoompanying diagram of the approach of three stars shows this action ; and this action is also of great importance in causing the *escape* of bodies from a condensing cosmic system.

Again, a star may plunge tangentially through a nebula, and be retarded enough to be unable to release itself ; hence it would revolve about the nebula and plunge through it at each revolution. The friction would cause it to lose velocity and this lessened velocity would make its orbit more and more circular; until, when the nebula shrank to be a sun, the two would form a binary star.

Should the evidence hitherto offered that

DIAGRAM ILLUSTRATING CHANGES OF VELOCITY THAT MAY OCCUR WHEN THREE STARS PASS NEAR ONE ANOTHER.

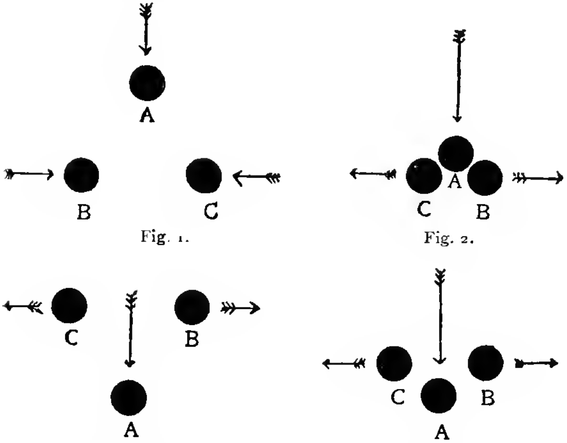


Fig. 1. Fig. 2.

No. 4. No. 3.

FIG. 1 represents two stars, B and C, about to pass each other. A, another star, is about to pass between the other two. The velocities, as represented by the arrows, are taken as about equal.

FIG. 2 represents C and B having passed each other. They have gained and lost velocity, whilst A is still approaching, so has gained and is still gaining velocity.

FIG. 3. The velocity of A is about the same as in fig. 2, the velocity however, has been gained and lost, but B and C have still further lost velocity.

FIG. 4. A has a much higher velocity than in fig. 1, as B and C are further from it in leaving than in approaching. Whilst B and C have a lessened velocity, and hence may be orbitally connected into a double star, whilst the high velocity of A may carry it out of the cosmic system.

partial impact occurs, and that it is an agent of tremendous constructive power, be insufficient to convince the sceptical, I must ask such, of their patience to pursue the subject further until their scepticism turns to a delighted conviction of the might of this constructive force. In order to do this, I must ask them to travel with me into the realms of selective molecular escape, to consider the formation of stars clusters and meteroic swarms, to investigate the evidence offered by modern photographs of nebulæ, to trace out the origin of the order manifest in the universe and solar system, and to glance at the wondrous interacting agencies which suggest that our universe is but one of many, and that the mighty Cosmos, as a whole, is infinite and immortal.

CHAPTER V

SELECTIVE MOLECULAR ESCAPE

THE ATOMIC THEORY—COMBINING AND NON-COMBINING MOLECULES—VELOCITY OF MOLECULES DEPENDS ON TEMPERATURE. CELIBATE MOLECULES AND COSMIC PIONEERS. DYNAMICAL THEORY OF GASES—GASEOUS EXPANSION—SORTING OF ATOMS AT HIGH VELOCITIES—VELOCITY DEPENDENT ON ATOMIC WEIGHT. GASES EVOLVED BY IMPACT, EITHER EXCEED THE CRITICAL VELOCITY, OR, ASSISTED BY ROTATION AND OXYGENATION, MAY FORM STAR CLUSTERS, METEORIC SWARMS OR SUNS. OXIDES ARE OF LOW VOLATILITY. SELECTIVE ESCAPE TENDS TO FILL SPACE WITH WANDERING MOLECULES.

Hitherto in these chapters the differences of chemical composition have been almost ignored, and this has been done in order that the ideas involved, by being less complex might be more easily appreciated ; but chemical constitution lies at the very foundation of Cosmic Evolution, and the details of chemical constitution must be understood before the wide areas the subject covers can be fully explored.

Dalton's far-reaching atomic theory has been the basis of most of the greater conceptions and discoveries of modern chemistry. That theory is that all substances are made up of ultimate indivisible particles of matter of extreme minuteness and known as atoms. There are altogether between sixty and seventy different kinds of substances known as chemical elements, the atoms of each of these different elements being assumed to be absolutely alike in weight and other properties, whereas the atoms of the different kinds of elements differ in these respects. Thus all the atoms of oxygen are assumed to be sixteen times as heavy as those of hydrogen, and when a combination of any of these elements occurs the product is found to be composed of some multiple of their respective atomic weights. Thus there are two combinations of oxygen with hydrogen, known respectively as water and peroxide of hydrogen. In water the weight of the oxygen is eight times that of the hydrogen, and hence we conclude that the molecule or ultimate particle of water consists of one atom of oxygen and two of hydrogen, whereas in the case of the peroxide the proportion is sixteen to one, and it is therefore concluded that the molecule is probably of one atom of each. It is not, however, always the case that the final particles of a compound are made up of the simplest number of atoms that are capable of grouping together ; in fact it is assumed that the molecule of peroxide of hydrogen consists of two atoms of oxygen united by affinity with two atoms of hydrogen.

There are two classes of these ultimate molecules : the ultimate molecules made by the combination of atoms of different elements and molecules containing only one element. Thus the conception of a free molecule of hydrogen is that it is made up of two of its ultimate atoms, and the free molecule of oxygen may be either made up of two atoms as it is in common oxygen, or of three atoms as it is in ozone, or oxygen that has been subjected to electrical or other agency.

Again, it may be assumed that if molecules are moving with extraordinary velocity and strike one another, that the molecule of hydrogen, consisting of two atoms, may be broken up and its molecules or ultimate particles may then consist of single atoms. In the case of hydrogen these separated atoms would tend to join again, but it is probable that at exceedingly high temperatures, that is at a high velocity, a very large number of the molecules are thus broken up, and there are many elements in which we believe that the ultimate atom may be also the molecule. This is especially the case with the group of recently discovered elements: helium, neon, argon, crypton and xenon—elements that have no affinities either for other elements or for themselves. They are consequently monatomic molecules without any apparent function in the solar system; complete celibates in fact, but just as human celibates make the best pioneers into little known regions, so it is probable that the function of these elements is to make their way into those parts of space where matter is very sparse. Hence I have called these elements Cosmic Pioneers, for they play a large part in the reconstruction of the systems in the scheme of Cosmic Evolution.

Since Dalton brought out his atomic theory, there have been a number of suggestions as to the possibility of elements being built up of more primitive material. The attempts, however, have not been attended with any very great measure of success; and although I believe that Professor J. J. Thompson's recent paper on "Particles Smaller than Atoms" is taking us in the direction of a profound discovery in electricity or ether, yet I am not at present of opinion that we have evidence that the elements themselves ever disintegrate and give off minute particles of their own material, and in these papers I rigidly use Dalton's theory of the absolute fixedness and indestructibility of the ultimate atom. Whilst I hold these views it will be well to mention that although it should be proved that the atoms are capable of disruption, it will in no sense affect the general argument of this theory; only it is well to clear the ground that the reader may know that no hypotheses are used in connection with this scheme of Cosmic Evolution other than those which are absolutely accepted laws of matter and energy. The Dynamical Theory of Gases is treated as an accepted truth. Atoms, then, to the student of this system of Cosmic Evolution, are indivisible minute particles, that enter into combinations and pass out of such combinations—that form molecules and break away from these molecules, but in themselves undergo no change.

We have spoken already of these molecules in their various states of solid, liquid and gas, and it is in connection with their condition as gas that we have now to follow up their study. The dynamical theory of gases tells us that at the same temperature and the same pressure, a litre of gas, no matter what its composition, will always contain the same number of molecules, whether these molecules be the lighest monatomic molecules or the heaviest possible compound gas. The reason why the light gas, and it may be the smaller molecule, occupy the same space as the larger, heavier kind, is on account of the rapidity of their motion. The space in which an ordinary gas exists is nothing like completely filled with the gaseous molecules, and it is frequently easy to compress the gas into one hundredth of its volume without compressing the molecules themselves. The reason the gas occupies so much space is that the motion of the molecules in consequence of their velocity forces other material out of the way, and what the lighter molecules lack in mass, they make up in velocity. In illustration of this, for instance, oxygen weighs sixteen times as much as hydrogen and moves one quarter as fast. It consequently strikes one blow to every four blows of hydrogen, but the hydrogen strikes not merely four times as often but with four times the swiftness. Hence hydrogen hitting four times as frequently and moving four times as fast gives a momentum of 16; while oxygen with a velocity of 1 and a mass of 16 gives also a momentum of 16; so that the pressure exerted by either gas is equal.

This difference of the velocity of molecules is of extraordinary importance in connection with Cosmic Evolution. Years ago Clark Maxwell suggested that without the interposition of energy, but simply by an intelligent sorting of the atoms, it was possible to overcome the process of the dissipation of energy. Now the different rates of the velocity of the molecules in a free cosmic system will actually sort the atoms by natural means. Let us assume that a body similar to 1830 Groombridge, that is a star moving with an enormous velocity, were to strike another similar star, and that both of these stars were made up of admixtures of cosmic elements. If these elements were in detached portions of the star, on the impact of the two stars all the molecules would approximately have the same velocity given them, but the oxygen molecules having the same velocity as the hydrogen molecules would be sixteen times as hot. The whole would of course be converted into gas, and consequently soon after the collision the temperature would become approximately equal throughout the mass. Then the hydrogen would be moving four times as fast as the oxygen. The oxygen would have lost and the hydrogen gained heat, that is the oxygen would have lost and the hydrogen have gained speed. Thus the lighter molecules will rob the heavier molecules of their speed in attaining a common temperature. With this velocity the hydrogen would possess sixteen times the power of escape from the general mass compared with the oxygen, and consequently if the velocity of the hydrogen be great enough, (and it will usually be great enough), it will start from the mass on a journey with a higher velocity than it is possible for the attraction of the body to arrest; so that we see there is a tendency, in a free gaseous cosmic sphere, at a very high temperature, for the molecules to escape from the surface in the inverse order of their atomic weights. Hydrogen will have a velocity on the average twice as great as the element next to it—helium (if it be in the monatomic condition); and so we find, that as the atoms increase in weight, they decrease in speed. Now it is clear that if a molecule start from the surface of a body, at any angle, after it has travelled a very great distance, it will be approximately travelling radially. Hence there is a tendency for the whole of the molecules to start on journeys as they reach the surface. The lighter molecules go with a higher speed and the heavier molecules at a lower speed. For a long time, of course, there is an admixture of these elements, but ultimately the quicker ones outrun their more leisurely companions and we have the gases sorting themselves into layers somewhat similar to those of a lily bulb, advancing in inverse order of their respective atomic weights. This tendency to separation I have called Selective Molecular Escape. Had the molecules velocity enough, we should find that the whole of them would arrange themselves (at a great distance from the place of impact) into approximately concentric layers ; but supposing the energy were too small to permit of dissipation of the whole of the gas, we should have the very lightest gases escaping the system altogether ; the intermediate remaining for very considerable periods at the limit of effective gravitation ; whilst the heavier metallic gases would gradually lose heat by radiation and be re-attracted back to the centre, forming, according to the amount of the rotation and the quantity of oxygen present, star-clusters, suns or meteoric swarms,

The reason oxygen is so important as to deserve special mention is due to the fact that this element in its combinations with other elements tends to render them very much less volatile than the simple elements are themselves. This property is exactly the reverse of chlorine, for the compounds of chlorine with non-volatile metals are often volatile, whereas the metals associated with non-volatile oxides are often volatile, as is instanced in the production of the remarkable oxide of zinc known as "Philosopher's Wool." The consequence is that if there be a considerable quantity of oxygen present, the separate elements tend to become non-volatile compounds that aggregate into dust, and again when we have a considerable rotation, there is a tendency for this dust to aggregate into nuclei and become orbitally connected with the general mass instead of shrinking directly towards the centre and becoming a sun, as would be the case were the heavier metals in the centre of the mass free from rotation and from oxygen. In that case they would develop into a single body of the nature of a dense nebula, ultimately becoming a sun. A full description of this part of the subject will be given in subsequent chapters.

The most important characteristic of selective molecular escape is its tendendency to give light molecules so high a velocity that they escape all gravitating systems and wander free in space.

CHAPTER VI

PLANETARY NEBULÆ

HERSCHEL'S CONCLUSION THAT PLANETARY NEBULÆ ARE HOLLOW SHELLS OF GAS—THEIR HUGE DIMENSIONS. RELATIVE DISTRIBUTION OF MATTER AND ENERGY AT HIGH TEMPERATURES. HOW SLIGHT IMPACTS CAN PRODUCE A SHELL OF GAS—ENDURING CHARACTER OF SUCH SHELLS WHEN ENORMOUSLY LARGE AND COMPOSED OF DENSE GASES. FURTHER INVESTIGATION NEEDED. PROBABLY THESE NEBULÆ ARE ALTERING THEIR DIMENSIONS. A STAR CLUSTER WITHIN A NEBULA.

In the preceding chapter it has been demonstrated, on the theory of Selective Molecular Escape, that after an impact of two stars of mixed chemical composition a gaseous envelope may be formed, associated or not with a central condensation, which central mass may ultimately result either in a star cluster, a meteoric swarm or a solar nebula. The existence of such a hollow gaseous sphere, in Herschell's opinion, is the only reasonable explanation of those extraordinary celestial bodies known to astronomers as planetary nebulæ and the following extract from the "Outlines of Astronomy"[1] gives Herschel's own account of them :—

"Planetary nebulæ are very extraordinary objects. They have, as their name imports, a near, in some cases a perfect resemblance to planets, presenting discs round, or slightly oval, in some quite sharply terminated, in others a little hazy or softened at the borders. Their light is in some perfectly equable, in others mottled and of a very peculiar texture as if curdled. They are comparatively rare objects, not above four or five and twenty having been hitherto observed, and of these nearly three fourths are situated in the southern hemisphere. On the disc of No. 3 (Herschel's list) and very nearly in the centre of the ellipse, is a star 9m and the texture of its light, being velvety, or as if formed of fine dust, clearly indicates its resolvability into stars. The largest of these objects (No. 5) is situated somewhat south of the parallel of *B* Ursæ Majoris and about 12m following that star. Its apparent diameter is 2′ 40″, which, supposing it placed at a distance from us not more than that of 61

---

[1] Page 644 seq. 1893

Cygni would imply a linear one seven times greater than the orbit of Neptune. The light of this stupendous globe is perfectly equable, (except just at the edge where it is slightly softened,) and of considerable brightness. Such an appearance would not be presented by a globular space filled with stars or luminous matter, which structure would necessarily give rise to an apparent increase of brightness towards the centre in proportion to the thickness traversed by the visual ray. We might therefore be induced to conclude its real constitution to be either that of a hollow spherical shell, or of a flat disc presented to us by a highly improbably coincidence in a plane precisely perpendicular to the visual rays.

Whatever idea we may form of the real nature of such a body, or of the planetary nebulæ in general, which all agree in the absence of central condensation, it is evident that the intrinsic splendour of their surfaces, *if continuous*, must be almost infinitely less than that of the sun."

Herschel urges the improbability of a single disc being presented to us exactly perpendicular to the visual ray. How infinitely improbable is it then that some twenty of these bodies should be presented to us in this position. Hence there can be no explanation of planetary nebula but that they are hollow shells of gas.

It has been shown that if an impact be of a very slight character, so that the third body produced is of small mass, the energy available will dissipate the whole of it, and every molecule of which it is composed will become independent in free space. The consequences of this possibility will be considered presently in connection with the formation of cosmic systems of the first order.

Were the impacting stars homogeneous, consisting of one chemical element only, dissipation of the whole of the molecules would also occur, even if a considerable portion—say one fifth—were sheared off from the stars; but when there is varying chemical composition, this would not be true of anything like so large a ratio, for selective molecular escape would cause the lighter molecules to rob the heavier of their energy. It is true that the passing of the lighter molecules out of the system leaves the denser material remaining of less mass than before, but the robbery of the energy is out of all proportion to the lessening of the mass.

The following numerical illustration shows in the case of spheres assumed to consist wholly of water, how great is the respective loss of energy as compared with the loss of matter in the case of a partial impact.

Water has the formula $H_2 O$. Its molecule consists of one atom of oxygen and two of hydrogen, and its composition is therefore eight parts of oxygen to one part of hydrogen. Assume that at first the energy is equally distributed throughout the mass ; then the oxygen is sixteen times as hot as the hydrogen. Now let the temperature become equalised ; then the velocity of the hydrogen molecule will be four times that of the oxygen molecule and the energy of an equal mass of hydrogen will be sixteen times that of oxygen. In other words each atom will have an equal store of energy, so that $\frac{8}{9}$ of the mass—that is the oxygen—will have $\frac{1}{3}$ the energy, and $\frac{1}{9}$ of the mass—that is the hydrogen—will have $\frac{2}{3}$ the energy ; that is with the escape of hydrogen $\frac{1}{9}$ of the mass will be taken away and $\frac{2}{3}$ the energy, and the remaining oxygen will only possess $\frac{3}{8}$ of the average energy it would have had supposing the mass colliding had been all oxygen instead of water. In equal masses at the same temperature the energy is inversely as the atomic weight. That is at 1,000 degrees absolute, a ton of hydrogen has sixteen times the energy of a ton of oxygen, 56 times that of a ton of iron, and 207 times the energy of a ton of lead.

Thus great is the contrast of the distribution of matter and energy in the case of elements so nearly related as hydrogen and oxygen with atomic weights in the proportion of 1 to 16. When we come to elements having a mean atomic weight of 200, as is the case with a very large group of elements, the translation of the energy in porportion to the mass dissipated become a very large ratio indeed : in other words in selective molecular escape the dissipation of the energy is enormously greater than the dissipation of matter ; so that even with a very slight graze, the difference of chemical composition would not permit the complete dissipation of the newly formed body. When the graze is considerable the material constituting the third body will divide, at all events temporarily, into three portions. The lighter molecules, such as hydrogen and helium will be dissipated completely into space beyond the limits of effective gravitation; the intermediate weights will be carried to its limits, and the heavy will be attracted back; but should the graze be less than will dissipate hydrogen and helium only, some of the heavier molecules will pass away as well.

Let us consider the case of a graze in which the ratio is such that only the lightest elements will be completely dissipated. Then there would be a large number of the heavier molecules that would travel outwards radially, until their velocity was very small, the decrease of motion being due to the attraction of the rest of the mass. If the position where the molecules came almost to a state of rest were very remote for the centre, as is actually the case with planetary nebulæ, and were the amount of the material left at the centre of mass small, it would take a very long period before the attraction of the central mass would cause the molecules in the shell to be attracted back to the centre. In some case the period would be certain to be some thousands of years. For example, in the case of the enormous planetary nebulæ described by Herschel as being in dimensions at least seven times the diameter of the known solar system.

A planetary nebulæ may consist of three

different classes of elements. It may consist of hydrogen and helium, but in this case so great would be the central attraction that the spherical shell of gases would be of transitory duration.

Secondly, it may consist of nitrogen and elements of approximate atomic weights, in which case the central mass left behind would not be of so large a ratio and the planetary nebula would be of a kind that would probably ultimately show something of the nature of a star at the centre, and would be of considerable duration; but for a planetary nebula to persist a very long time there could not be a very great central attraction. Therefore in this case either the impact should not cut into the dense metals at the centres of the spheres, or the planetary nebula would be largely made up of the heavier elements. Possibly this may be demonstrated to be the case in some instances with further spectroscopic research.

In the case where the dissipation did not extend so far as to carry off any considerable quantity of oxygen, these heavier elements would combine with the oxygen as already suggested, and the compound molecules would aggregate into cosmic dust, and this would cause the curdled appearance described by Herschel.

A persistent planetary nebula is probably one that has been formed by bodies coming into impact and striking off so small a mass as to dissipate most of it into space. Most of the lighter gases were so dissipated whilst the intermediate and heavier materials were taken to the limits of effective gravitation and sorted according to velocity, whilst, as a rule, the amount left at the centre was small. It would be well to measure again those planetary nebula which have stars at their centres to ascertain if they have sensibly diminished in volume since the time when Herschel made his records.

However, it is probable, although it may be slowly, that all planetary nebula are altering their dimensions. If young, in relation to cosmic existence, they would probably slowly increase in size; if a little older they would be, as it were, at a comparatively steady condition, but as they grow old the pace of their diminution would usually accelerate.

The star that Herschel describes as having a velvety texture, is probably, as indicated by him, a star cluster, as the next chapter will show. A star cluster must at all events in many partial impacts, be a transitory condition before the central condensation of the mass.

CHAPTER VII

STAR CLUSTERS

STAR CLUSTERS THEIR BEAUTY, PROPORTIONS, COLOURS AND PHENOMENA. SIR ROBERT BALL ON SELECTIVE MOLECULAR ESCAPE—RESULTS OF THE PROCESS—THE LIGHTER MOLECULES ESCAPE FIRST—OXYGENATION —FORMATION OF DUST GLOBES—CONDENSATION OF SUNS—INFLUENCE OF ROTATION—WHIRLING COALESCENCE AND THE EVOLUTION OF CLUSTERS—PERTURBATION WITHIN THE GROUP—VARIABLES WITHIN THE CLUSTERS—THEY EXIST AND SHOULD EXIST—LOCALISATION OF VARIABLES—IMPACTS WITHIN A CLUSTER—ENTRAPPING POWER OF NEBULOUS MATTER—DOUBLE STARS MORE PERMANENT THAN VARIABLES—DOUBLE STARS WITHIN CLUSTERS.—CLUSTERS DEVELOP INTO PLANETARY SYSTEMS.

Marvellous as is the beauty of Saturn's Rings, of Venus in quadrature, of those lovely cosmic flowers the glowing nebulæ, yet according to astronomers, the wondrous star clusters surpass everything else for brilliant magnificence. These groups of celestial gems may sparkle like diamonds of the first water, or they may shine with many a varied tint, some blue beyond the Oriental sapphire, some vivid green, or red, or purple. Some of the groups are all white;

some, as in the constellation of the Southern Cross, are white, interspersed with red, blue and green stars; while the most wonderful of all the clusters, that in the Toucan, is of an exquisite rose tint. Then, the number of component stars is wonderful; in most clusters they may be counted by hundreds, in some there are many thousand independent points of light, every point of light a sun—perchance bearing a planetary system with it. What possibilites unfold themselves! Think of any one of these Solar Systems threading its way through the maze of the other suns! What vicissitudes it must encounter! For hundreds of years it might revolve amongst the densities of star distribution at the centre of the system; then its orbit might be deflected, and for thousands of years it might travel towards the exterior of the cluster.

As for the sudden adaptations that would be brought about by natural selection on such a sun and its satellites, the changes from tropic to arctic during the great glacial epochs of the earth would be nothing in comparison. Then, again, how the heavens must alter in aspect within those wondrous coloured clusters, where in one part the emerald and the ruby enhance their mutual beauty, and in another the topaz and the sapphire outglow each other! Imagine oneself the inhabitant of a planet lit by a ruby sun and an emerald sun! Consider the brilliant pictures—and the shadows—every shadow chromatic, and every shadow double, one coloured red and the other green! But if these wonders seem too much for human imagination, we need not try to conceive the effects for the inhabitants of a planet within a coloured star cluster; only an infinity of omniscience could accomplish the task.

The great Humboldt asked this most suggestive question: "How can these systems be maintained—how can the suns, crowding at the interior of star clusters, fulfil their revolutions freely and without clashing?" Do they revolve without clashing? The answer is: Almost certainly not. One of the latest new stars was in a cluster, and the brilliant point of light often noticed in such groups is doubtless the heated wreck of colliding suns. Every such impact strews the centre with gas which exercises a retarding effect upon the suns passing through it; every such collision lessens the motive energy of the cluster and helps to weld it together.

But this action is discussed in the latter part of this chapter. The history of clusters is a long and difficult matter, which must be told slowly and systematically. We ask: How did these galaxies of suns originate, and what force united all these giant orbs into magnificent concordant groups? My fellow-students must enlarge their patience, for I want to trace complex agencies, to follow the flights of varied molecules, and to contemplate protean interchanges of matter and energy. As we ascend in the research of grazing impact, we look out upon a series of problems so fertile in result, so infinite in potentialities, that our feelings are exactly the reverse of Alexander's: the student of impact will shed no tears over a conquered world; his sphere is boundless; in every direction new avenues of investigation are found and new fields of observation expand before his delighted vision. And although vicious specialisation will doubtless invade its domain, yet so wide is the basis of experimental science required for preliminary comprehension that this particular disease will have but slight scope, or effect.

If the original proper motions of the colliding pair forming Nova Aurigæ were small, the pair must have been respectively four thousand and eight thousand times the mass of our sun. A grazing impact of such a pair of orbs would consequently possess enough matter to make a cluster of stars, and if we can show that the conditions for their formation are present, the problem is solved. I have suggested reasons for supposing that dark suns may have a higher average independent velocity than luminous orbs. Imagine that two such dead suns, with independent velocities, were to collide deeply. The nebula produced would be intensely heated, and would rotate. If two bodies like our own sun were to collide completely, the impact would not convert them into a nebula; but our sun is made up of different chemical elements, from the very light atoms of helium and hydrogen to the heavy ones of lead, gold and platinum. The collision turns the forward motion of the mass into a motion of the particles, that is, into heat. It would not matter whether the mass were all hydrogen or all lead, the rate of the molecular motion would be the same; but the lead molecules of the same speed as hydrogen would be more than two hundred times as hot. So, in a sun of mixed elements, immediately after impact the speed of the atoms would be the same and the temperature different. But mixtures tend to equalise temperature. Then the cool hydrogen gains and the hot lead loses heat until they have equal temperature. Now comes into play the wonderful principle described under the heading of selective molecular escape. We understand that a body which travels fast enough may leave a cosmic mass and entirely escape. Hence, when at the same temperature, light atoms may leave the mass and the heavy ones may not be able to do so. But if the central mass be very small then every molecule may leave the body.

All who have studied partial impact know the fundamental thought of the whole theory is: A small ratio graze would be as hot as a large ratio graze; the grazed parts would coalesce, and the velocity of the molecules would be so high that, if the graze were slight, the attraction of the mass would not prevent their escape and entire dissipation throughout space. This idea of gaseous escape, discussed in its many modifications, in papers published nearly a score of years ago, is now taking its place in literature. Sir Robert Ball, who has succeeded Proctor as a popular exponent of astronomy, deals with the subject of molecular escape in a recent article on Mars. He says:—"But the chief interest that the principle we have laid down possesses is found in the explanation which has been given of it. That explanation is both so recent and so remarkable, that I am glad to have the opportunity of setting it forth, as it has an important application to Mars. The view of the subject here given is due to Dr. G. Johnstone Stoney, F.R.S., who recently communicated it to the Royal Dublin Society. Modern research has demonstrated that what we call a gas is in truth a mighty host of molecules far too small to be perceptible in the most powerful microscope. Each of these molecules is animated by a rapid movement, which is only pursued for a short distance in one direction before a *rencontre* takes place with some other molecule, in consequence of which the directions and the velocities of the individual molecules are continually changing. For each gas the molecules have, however, a certain average pace, which is appropriate to that gas for that temperature, and when two or more gases are blended, as in our atmosphere, then each molecule of the constituent gases continues to move with its own particular speed. Thus, in the case of the air, the molecules of oxygen, as well as the molecules of nitrogen, are each animated by their characteristic velocity; and the same may be said of the molecules of carbonic acid, or of any other gas which, in more or less abundance, may happen to be diffused through our air. For two of the chief gases the average velocities of the molecules as as follows:—oxygen, a quarter of a mile per second; hydrogen, one mile per second. In each case the temperature is taken to be 64° C. below zero. being, presumably, that at the confines of the atmosphere. It will be noticed that there is a remarkable difference between the speeds of the two molecules here mentioned. That of hydrogen is by far the greatest of any gas. We may now recall a fundamental fact in connection with any celestial body, large or small. It is well known, that with the most powerful pieces of artillery that can be forged a projectile can be launched with a speed of about half a mile a second. If the canon were pointed upwards the projectile would soar to a great elevation, but its speed would gradually abate, the summit of its journey would be duly reached, after which it would fall back again on the earth. Such would undoubtedly be the case if the experiment were made on a globe resembling our own in size and mass. But on a globe much smaller than the earth, not larger, for instance, than are some of the minor planets, it is certain that a projectile shot aloft from a great Armstrong gun would go up, and would never return. The lessening gravitation of the body would fail to recall it."

Thus has the idea of Selective Molecular Escape become public property.

An obvious result of this selective action is that the coalesced mass is robbed of its light gases. Thus, at the same temperature, the mean speed of hydrogen is four times that of oxygen, about seven times that of iron and fourteen times that of lead. So, after a time, the elements, helium, hydrogen and other light gases will be rushing on into space, speeding ahead; whilst the lithium, nitrogen, oxygen, neon and others are following in the order of their atomic weight. But oxygen, although not heavy, has great affinity for silicon and many metals, forming with them non-volatile and coalescent molecules. Hence oxygen is largely entrapped, and, as the mass expands, this chemical action sets in; and a very rare, very stupendous rotating luminous dust globe—or, perchance, dust shell—is formed. Gradually, as with rain and hail, coalescence of particles takes place. If there were no rotation, this dust would coalesce into a sun; but, with rotation, such is not necessarily the case. The particles will be attracted to the centre, but their tangential motion will make each move in an orbit. The particles will continually cross each other's paths, coalescing and growing larger and larger; but, as selective escape has taken everything of the nature of nebulous matter out of the system, there is nothing to offer resistance to these growing particles; they become fewer in number as they increase in size, and the huge mass of glowing dust is slowly converted into a star cluster. It is possible that a very deep case of whirling coalescence may form a star cluster, for nearly all the conditions required would be present. But the subject is one of great complexity.

It is scarcely likely that there can be any definite order as to the orbits of stars in a cluster. The perturbations throughout the group must be so tremendous that impacts should be frequent; and it is possible that in star clusters we might thus study every peculiarity of impact were it not for the difficulty in getting detached spectra.

In some star clusters variable stars exist in considerable numbers, and in portions of other star clusters variable stars seem to have concentrated themselves; whilst a great number of star clusters that have been examined appear to have certainly not a greater proportion of variable stars than are to be found in other parts of the heavens.

On the Theory of Partial Impact, a variable star is a star that has come into a grazing collision with another star, and has had a portion struck from it. This scarred portion becomes in this way highly heated and the body has been set rotating, and thus showing alternately the heated and the cooler sides, gives a variation of light. Consequently in attempting to account for the localisation of variable stars in special clusters and in parts of clusters, the subject we have to study is the cause of a series of impacts occurring in a comparatively short time and in approximately near vicinity.

The stars of a star cluster are probably smaller than the average independent star, and are possibly, also, of higher average temperature.

Being associated into a group connected by gravitation, the velocity of the stars in their orbits is probably greater than the mean proper motion of other stars.

From their relative nearness compared with other stars, it is probable that impacts would occur more frequently in star clusters than between a similar number of independent stars. In a star cluster also it is probable, that the variability that would be produced by a grazing impact would not be of so long a duration as would be be the case with stars of greater mass and lower temperatures; the heated portion produced in probably gaseous bodies certainly tending to diffuse itself over the general surface of the body rather than to remain in a single position as would be the case with a dark body such as Mira, which has a lake of fire on one side.

It is an uncontested fundamental principle of the Theory of Partial Impact that if the mutual velocities destroyed in the coalesced part be above a given speed, proportionate to its mass, a nebula must be produced, and this in spite of any difference of chemical composition. Thus a lead or platinum globe would, in such circumstances, become a nebula just as certainly as a sphere of hydrogen, the temperature produced by the impact being proportional to the atomic weight, and the molecular velocity and consequent power of diffusion being equal in all elements.

In star clusters partial impacts tend to distribute gas, and this tendency is aided by the high temperature of the stars in the cluster and the high velocity of their motion. If the impact of stars take place near the centre of the cluster, the gas will tend to be distributed comparatively equally on all sides of the disturbance. This gas will retard the stars that pass through it, and will tend to produce other impacts. This again will result in more gas being distributed, leading to other collisions and consequently to other variable stars. Moreover, we must remember that no internal disturbance will lessen the general rotation of the mass, and consequently the number of stars that will come into impact has a distinct limit. Possibly something of this sort may occur; a single impact happens that distributes gas and causes another impact. More gas and other impacts follow. Presently those stars that can possibly be so entangled diminish in number and after a time we have a cessation of impacts, leaving a distribution of variable stars.

As already shown, if the original impact take place near the centre, this distribution of variable stars will tend to be through the whole star cluster. If the original impact take place on one side of the cluster, the fresh impacts produced by the retarding gas generally occur in the same vicinity. As the variability would probably die down in star clusters more quickly than elsewhere, although the impacts would be more frequent, the number of variable stars would not on an average be greater than amongst other stars.

Although it is reasonable to suppose that variability will die down quickly in star clusters, this does not apply to the entrapping of stars to form double stars, for a pair of stars, once entrapped, save under very unusual circumstances, remain as a double star until fusion into a larger system occurs, so it is possible that there may be a considerable number of double stars in any given star cluster.

There would probably be an immense number of double stars were it not that another factor comes into play. The greater the original motion of the stars before mutual attraction commences, the greater is the probability of escape after the impact. If the stars were at rest when they were first attracted towards each other, the smallest graze would inevitably blend the pair. With a star of the character of 1830 Groombridge, it is almost certain that were more than half the mass cut from the star the remaining portion would pass off into space and would not be entrapped. Hence it would only be in the case of a considerable graze in a star cluster that double stars would be produced; but taking the sum of the actions there seems reason to suppose that as a whole we should expect star clusters to be richer in double stars than a similiar number of stars in ordinary star distribution.

As to the future of star clusters, almost certainly impact will cause the central condensations to increase until the temperature will volatilise some of the suns, and this vapour will be a retarding trap for those suns that pass through the centre. Ultimately, this centre will become a huge flaming sun, with a vast system of associated dead suns, that will one day be giant planets

How rich are the possibilities of the Cosmos! The pendulum of Eternity sways, and a pair of dead suns collide—each, possibly, with innumerable satellites, that, after the collision, revolve in orbits around a huge fire-mist. Then the fire-mist cools and coalesces, and becomes a star cluster. The stars of the cluster collide, again volatilize, again coalesce and become one vast sun, with the cooling outer suns—now planets—teeming with such lofty life as evolution may produce on their immensities during the thousands of millions of years of action that but complete this swing of Eternity's pendulum!

We have considered impacts that may produce star clusters. It is easy to realise smaller collisions producing the dust swarms, which, under the influence of heat, of internal friction, of reflection of solar light, and of electricity, occasionally adorn the sky with the waving plumes of our beautiful cometic visitants. The discussion of these erratic but wondrously attractive wanderers we will discuss with other related marvels in Chapter X.

CHAPTER VIII

THE SOLAR SYSTEM.

IMMENSITY OF THE SUN—ITS CYCLONIC SPOTS, ROTATION AND PROPER MOTION. THE PLANETS AND PLANETOIDS—THEIR RELATIVE MOTION, ROTATION AND INCLINED AXES. LAPLACE'S NEBULAR THEORY—ITS WEAK POINTS. PLANETARY SEASONS, DAYS, MOONS, ECLIPSES AND TIDES. WHY THE MOON PRESENTS ONE FACE TO THE EARTH. THE SUN'S FAMILY.

The sun—the chief controlling power of the system that bears his name—is a huge ball of fire more than a million times the volume of the earth ; a seething, flaming, stormy mass of such magnificent dimensions, that, in point of distance alone, we could not discern a body of the earth's size at the sun's centre, and the orbit of the moon would be a comparatively small circle on his disc. Were the earth the centre of the sun, the circumference of the sublime orb would be twice as distant as the moon is from us now. The cyclones on its face, which we call spots, tell us that our parent globe is rotating in about twenty-six of our days ; and it is thought, such is the tremendous nature of its tumult, that the polar regions whirl round at a different rate from the equatorial. Certainly this is not impossible; nay, it is even probable.

The sun travels in space—taking his family with him—at the rate of about four miles a second, in a direction slightly inclined to his own polar axis. As stellar motions go, the sun's rate is distinctly leisurely. Some of the stars fly at the rate of hundreds of miles a second; and, when they get up speed for a stellar encounter, the evidence proves that they may strike one another with the inconceivable swiftness of thousands of miles a second. It is of no use to try to realise astronomic numbers; we can calculate them and talk about them; we can never appreciate them. Four miles a second, although a small cosmic velocity is a tremendous speed as we know motions. When we look at an express train running along creating a whirlwind of dust, paper, leaves and other *debris* a dozen yards on either side of its mile-a-minute course, we have a feeling of the irresistible; yet had the train the sun's speed it would possess 57,000 times the energy it has at a mile a minute. The sun's motion, combined with planetary revolution, causes the earth and all the other planets to move in sloping spirals. Of the sun's motion in space, however, we need say little at present. We will consider him as at rest, with the planets revolving round him, and the moons around the planets. There are eight planets; four small dense inner planets, and four outside large planets of less density. A great gap occurs between these two series, and therein revolve many hundreds upon hundreds of minute planets, or planetoids, as they are called. "Bode's Law" describes a rough order in the position of the planets, and, according to this order, a planet was missing, for which a society of astronomers was constituted to search. On the first day of the last century Ceres was found in the gap; the following year Pallas; then Juno, then Vesta, and so on and on, till nearly 460 tiny planetary spheres are either named or numbered. The two groups into which the planetoids divide the planets are: the inner group, Mercury, Venus, Earth, Mars; the outer, Jupiter, Saturn, Uranus, Neptune.

The nearer to the sun, the more quickly the planet travels; thus Mercury travels at about ten times the speed of Neptune, and completes its circuit in eighty eight days, while Neptune takes more than sixty thousand days to complete one revolution. All the planets revolve, roughly speaking, in one plane. All but one rotate in the same direction that they revolve in. It was this wonderful order that led Laplace to his exquisitely beautiful theory. His nebular hypothesis of the origin of systems has, doubtless, a good deal of truth in it; but his theory that planets and moons originate by the release of rings has, I am afraid, to be given up. Anyway, the planets' axes being at all angles, and Uranus even believed to go the wrong way, makes the theory difficult to the accept in its entirety.

Of the origin of planets, I shall hope to show something presently, far less fascinating than the ring theory, but one that accords with many of the peculiarities of the system.

Thus then the planets are a series of eight globes divided by the belt of planetoids into two groups of four each. All the planets and planetoids speed on in their course around the sun in one direction; and all, save the planetoids, roughly speaking, in the same plane. All but one are spinning in the same direction that they revolve in, but the axes of their rotation are inclined very differently. Jupiter, the giant planet, is nearly upright, whilst Uranus has its axis almost in the plane of its orbit. Venus is inclined more than an angle of 45 deg.; whilst the earth, Mars, and Saturn are all tipped a little more than the fourth of a quadrant. The tipping of the axes produces the seasons. So it is always spring-time in Jupiter; whilst poor Uranus presents one pole to the sun for about a quarter of a century; then spring comes, and for twenty-five years he is side on to the sun, gradually presenting the other pole. So roughly for twenty-five of our years Uranus has a day and night corresponding with his winter and summer; when autumn and spring come the days and nights correspond with his rotation. If there are inhabitants they must lead a strange kind of life. I suppose they travel with the summer and chase it round the globe. Venus has tremendous seasons, twice as acute as those of the earth; and there the sun is about twice as hot. The seasons of Mars and Saturn are similar to the earth's, only Saturn's year is about thirty times as long as ours.

The days of Mercury, Venus and Mars are about the same length as the earth's; whilst

Jupiter and Saturn have days less than half as long.

Most of the planets have attendant satellites; generally, these revolve roughly in the same plane as the equators of the planets to which they belong, our moon being about five degrees out; so that the apparent path of the moon in in the heavens does not correspond with that of the sun. As far as the moon is concerned, what is called the harvest moon is the only characteristic of seasons. The moon rotates once a month; and so always keeps the same face to us. As the sun sometimes shines on the other side of the moon, the face we know is then in the dark; and when by accident the moon gets fairly in front of the sun we have an eclipse. But as the disc of the moon, owing to altered distances, appears sometimes smaller and sometimes larger than the sun, we get different kinds of eclipses, annular when the disc is not large enough to cover the sun, total when it is. The eclipse of the moon is due to its getting into the earth's shadow. That the moon always presents the same face to us is probably due to an interesting tidal action. Both the sun and moon cause tides on the earth; but, owing to the nearness of the moon, the action is chiefly lunar. When both act together we get the spring tides. The so-called tidal waves are generally volcanic in origin, due to the earth shivering when internal contraction causes the surface to crush. The tides bulge up on both sides of the earth ; away from, and towards the moon. She attracts the near ocean more than the earth ; she attracts the body of the earth more than the distant ocean. Thus one side bulges up because it is pulled away from the earth ; the other side because it is left behind. But if the moon produces such tides on the broken-up ocean, what must it have done when all the earth was fluid ? And what must have been the tides in the moon produced by the earth fifty times as big and twice as dense ? The earth is nearly a hundred times as heavy as the moon. Probably the moon does not possess the earth's proportion of gold and platinum at her centre. However that may be, the tidal action of the earth on the moon when she was liquid must have been enormous. Tides act as a brake and stop rotation ; so if we were to put up water-power engines and use the estuaries as mill ponds we should, as it were, utilise the brake that is stopping the earth. Just as sparks fly out of a railway brake because of the change of motion into heat, so the tides warm the water of the oean. Were we to intercept the water and do work by tidal engines, there would be just the same amount of heat produced finally.

The tremendous earth tides on the fluid moon acted as a brake on the moon's rotation, and so slowed it down until it presented the same face to the earth. But the younger Darwin has demonstrated that not all this energy went to warm the moon. It was converted into potential energy, and sent the moon to a distance, much farther from the earth than it formerly had ; and probably the nearer planets have had their distances from the sun increased in the same way. Of course, when the moon was nearer, the earth tides were higher, and, incidentally, the atmospheric geological agencies were greater than they are to-day.

The moon probably belongs to the sun's true family, as do also another set of far smaller bodies, the meteors that constitute the zodiacal light ; whilst the periodic comets and meteoric swarms are adopted children, and the errant comets only passing visitors.

The zodiacal light described on page 141, is a huge, bun-shaped, luminous mass, often to be seen after the sun has set, sticking up aslant to the horizon in the plane of the ecliptic. I hope further to show that, in one state of the solar system, much of its matter consisted of countless myriads of millions of meteoric masses—coalesced molecules, and cosmic dust generally, all whirling in an atmosphere of rare gas. The zodiacal light may possibly be the remains of this *débris*, not yet absorbed by the sun. Those bodies that revolve near the sun must move with a velocity of over three hundred miles a second, and if a large one met a dense errant body visiting the sun—from an opposite direction—there would be a collision that would easily account for the brilliant solar flashes, and for that particular one that produced a few years ago such a violent magnetic storm that upset our telegraphic instruments and culminated in the most beautiful series of auroræ at both poles of the earth.

The sun, planets, moon, and zodiacal light are possibly legitimate relations united into a group during the great collision that wedded the two pre-solar masses from which I imagine the system originated. The members of the family adopted since would not weigh very much. There are a few comets and meteoric swarms that we know of; there may be an infinity of meteoric swarms we do not know of; because only those that intersect the earth's orbit, and sometimes plunge into our atmosphere, are visible to us. There may be myriads of bodies other than comets revolving in our system that we do not see. We see comets because of their physical condition. Comets are probably swarms of particles orbitally connected. When these get near the sun a tremendous tidal action sets up, that makes the constituent bodies rub one another and collide in various ways, producing luminosity by impact and electricity by friction; and so our dust visitor lights up and becomes visible. Were he solid we should not see him. The zodiacal light, comets and meteors are treated in detail in Chapter X.

Such then is our solar system, and in the next chapter an attempt will be made to give a definite account of its genesis.

CHAPTER IX

THE ORIGIN OF THE SOLAR SYSTEM

AN INCIPIENT SOLAR SYSTEM DEDUCED FROM IMPACT. HYPOTHESES OF LAPLACE, LOCKYER, AND PROCTOR NOT ACCEPTABLE—TIME RIPE FOR A NEW HYPOTHESIS. FUSION OF TWO SUNS—THE PLANETS REGARDED AS STEP CHILDREN—TWO GROUPS OF PLANETS IN THE SOLAR SYSTEM—THE SOLAR SYSTEM POSSIBLE AS THE RESULT OF THE COLLISION OF PRE-EXISTENT SYSTEMS OF SUNS AND PLANETS. EFFECTS OF GRAVITATION. IRREGULARITIES OF THE SOLAR SYSTEM—STEPS IN ITS GROWTH—WHY THE INNER PLANETS ARE DENSER THAN THE OUTER—JUPITER'S UPRIGHT AXIS ACCOUNTED FOR—MOONS ARE ENTRAPPED BODIES—EFFECTS OF TIDES UPON THEIR ORBITS. ORIGINAL AND ACQUIRED QUALITIES THAT HAVE LED TO THE SYMMETRY OF THE SYSTEM—ASTRONOMY AND GEOLOGY CONSONANT.

We have seen how a star cluster may originate and may become an incipient sun with satellites, whose orbits are at all angles. It is also easy to realise how a nebula may entrap bodies which, on the shrinking of the nebula into a sun, may become planets revolving in all directions. But without the idea of impact to originate a common rotation, it is difficult to understand the evolution of systems such as the one of which our earth is a member—a system in which the sun and almost all of its satellites rotate, and all the planets revolve, in the same direction and roughly in one plane.

The exquisitely ingenious hypothesis of Laplace, of the release and coalescence of nebular rings, has fascinated mankind for generations; and although it is no longer fully accepted, it leaves much fertile thought. The same may be said of the meteoric hypothesis of Lockyer and Proctor. The insuperable difficulties afforded by the dynamical theory of gases as against Laplace's theory does not apply to the meteoric idea; but, amidst the wondrous order of the system, the irregularities in the directions and orbits of the moons and planets, and of their axes, are too great to be accounted for on the meteoric hypothesis, so that although it was once fairly well known, it has almost passed out of literature. The ground is, therefore, clear for a new hypothesis, could a reasonable one be found.

It is possible, that the sun is the result of the collision of two bodies that have fused and coalesced, whilst the planets existed before the collision occurred. The union of the two bodies that made up our sun was probably a case of whirling coalesence in which the two became one.

The planets are not the offspring of the union; they are stepsons and daughters. Whether all belonged originally to the one, or were divided between both parents, it were hard to tell, perchance we may never know. Possibly the four inner planets may have belonged to the one, and the four outer to the other. They each form a set, the members of which have a close resemblance to each other; each group is so unlike the other group, that the two groups may not be related. Still, when we come to consider the evolution of such a system, it seems almost inevitable that some of this contrast of character between the inner and outer planets must have come about during their later evolution; so that much latitude of conjecture remains which further research may narrow. Thus, in a general way we may imagine the birth of the solar system.

Two vast globes are rushing in upon one another, one or both attended by satellites. Any of these satellites that plunge deeply into either body are at once burnt up—as the meteors of a

November shower are dissipated by our atmosphere—but all do not so plunge. As the great globes impinge upon one another some of the satellites are carried forward and escape the general conflagration.

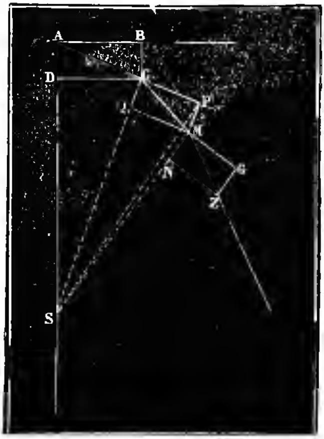
The solar system does not look as if it were produced by a partial impact in which a portion of each globe passed forward into space. The orbs, probably, plunged deeply into one another, and the parts not actually meeting were carried forward as huge tongues of fire that whirled around the general mass and were absorbed into it. All the agencies of an impact would be at work—intense heat, axial escape, selective escape and rotation. But the enormous attraction modifies all these agencies. The gravitating power is not small as it would be were a portion struck from each body. Both the entire bodies have coalesced, and the mutual attractive power neutralised the expansive effect of heat, and stopped the escape of molecules, except the lightest and those favourably situated. Doubtless there never has been a cosmic impact that did not strew space with countless wandering molecules. But in the origin of the sun this was not a large factor. The impact caused a whirl that swung the materials of the bodies into a huge bun-shaped rotating nebula, possibly always dense at the centre, but very rare at the exterior, and probably extending beyond Neptune; at least, the very circular orbit of that planet suggests that it was so, although this is not necessarily the case. The tidal stoppage of its rotation may have greatly enlarged its orbit, for we must remember that although tidal action would be very small at Neptune's distance, yet it would not take much work to push the planet further away from the sun. Anyway, that is a question mathematicians may probably answer. Certainly, if the solar system was formed in this way, the outer margin of the nebula extended to an enormous distance.

I have spoken above of axial escape. This action is especially characteristic of a case of whirling coalescence such as probably originated the Solar System. It is of especial interest in the case of the origin of the universe and will there be described in detail. It suggests that at the centre of two coalescing bodies a tremendous pressure is produced that can find no relief save axially and in this line in both directions material is shot out of the system.

Let us now gather up our ideas. Two bodies with satellites have collided, have coalesced, the non-coalescing parts swirling around each other; and this onward motion, combined with the expansive effect of heat, and its other result—molecular escape—has converted the two bodies into a nebula. The original satellites that formerly revolved without any order are swung forward by the onward rush of their parent orbs. Some are disintegrated; but some escape; some cannot fly away entirely—the attraction is too strong; hence they revolve in highly eccentric orbits. Had they been originally at rest they would have been thrown into a single plane and would all revolve one way; and in their passages through the nebula would all tend, as Laplace has shown, to rotate in the same direction. But they were not at rest around their central body; they revolved, and probably rotated. All these motions would tell in the final result, and fully explain all the irregularities of the system.

This, then, is an account of the possible union of the two bodies that formed the system. The final evolution of the planets is a matter of some difficulty. Much of their development has already been discussed in detail in earlier papers. But the complexity of the process tends to become bewildering, so we will only give a very general glance at some of the agencies that have converted that apparently

Diagram of the Orbit of a Planet.



S represents the sun and A the earth. In equal times it should fall to D and be carried by its velocity to B; the position it attains is C. Again, in equal times it would fall to Q and be carried by its onward motion to P, it consequently reaches M. The same agencies take it to Z. Clearly in the next revolution when it reached A, if the sun now disappeared, there would be no fall, hence it would reach B. If the sun were lessened it is clear the earth would pass between B and C, and consequently at the opposite end of the major axis it would be further from the sun, and the orbit would be more circular. Hence as seen in diagram page 73, the perihelion distance will be increased and the stars not impact again, and in the case of the orbits of the planets, all material lost before aphelion distance is reached will make the orbit more circular.

awful chaos of fire and conflict into the order and method that now remain.

The accompanying diagram of the orbit of a planet illustrates the interaction of the centripetal and centrifugal actions.

In the eye of the mind we watch the flight from the central fire of the planets and, perchance, countless smaller bodies. We watch the gigantic fire-mist whirling and expanding until it is many hundreds of millions of miles in diameter. We see the planets gradually lessening the speed of their flight, and presently commence their fall back towards the centre. They plunge deeper and deeper into the fire-mist, and all the gas outside their orbits has no influence in causing their return. Hence the orbits become more circular. But in the nebula the body becomes heated and expands, gathering the gas of the nebula towards itself. The bodies cross one another's path, and will often coalesce. Almost every such coalescence will tend to make the orbits more circular, to cause the rotation of all the planets to agree in direction, and the axes to become more perpendicular to the plane of the orbit. It would also bring this orbit into the plane of the general rotation of the nebula. Any planet that came near the centre would be intensely heated, and hence there would be a tendency to lose light molecules ; whilst, on the other hand, this body would tend to pick up the heavy molecules that selective escape would have left near the centre of the nebula. Thus, the inner planets would tend to be small, and to consist of dense material, and the outer planets large and less dense, exactly as we find them in the solar system. Selective escape would probably dissipate much hydrogen, helium, neon, nitrogen and argon but the energy proportionate to mass would not be great enough to do this at all effectively.

The giant planet Jupiter has probably been largely formed by impact and accretion, owing to its being in the centre of the storm of meteors that would be produced by coalescing molecules, and hence its axis is very upright. I think Proctor was the first to point this factor out. The moons were probably bodies entrapped by the planets when nebulous. The orbits of the moons have probably increased by tidal action ; much of their potential energy of expansion would become energy of rotation, and this by tidal action would turn into potential energy of distance from their planet. I cannot believe that the belt of the minor planets, or the meteors constituting Saturn's Rings, could have been present when either the solar nebula extended beyond the planetoids, or Saturn's volume extended beyond his rings. I believe in one case a planet, and in the other case a moon, has been blown to pieces by a body plunging into their mass. Those who have argued against this origin by explosion, have overlooked a number of agencies that have been effective in giving the present orbits to the planetoids.

Of the origin of the very imperfect order of the distances of the planets, called Bode's Law, I have given a full account in former technical papers, but my space does not permit me to discuss it here. Enough has been said to show that there was a vast series of agencies at work, tending to give the wonderfully majestic order to the system of which our earth is a member.

It may reasonably be asked why the solar system did not develop into a meteoric swarm, and then a small star cluster, before its final condition as a sun. I believe the answer to this to be, that it was not a case of partial impact, and consequently, as already suggested, only part of its gaseous constituents were sent out by molecular selective escape. Therefore the meteors, as they formed, revolved in a nebula that all the time lessened their velocity and entrapped them.

It would seem, then, that there would be a tendency for the contracting nebula to entrap all but the larger bodies. But these larger bodies would also possess an entrapping action. The planets in their intermediate state would probably have associated with them a large nebulous atmosphere, that the extreme tenuity of the solar nebula would not be able to sweep away. Such atmospheres would readily entrap bodies moving through them at approximately the same velocity, and such bodies would become moons. In other words, the contracting solar nebula would tend to entrap all but large masses. And the nebulous planets, in the same way, would tend to entrap and absorb all but masses relatively large to the mass of the planet.

We must remember there is an area even about a small planet, where the planet's gravitation is greater than the sun's gravitation from the same spot in space. Thus it seems probable that the planets might entrap moons. And in all these cases we must also keep in mind the fact that the orbits were probably much smaller, and have increased in size by tidal action, converting their energy of rotation into potential energy of distance, the same agency applying, of course, both to the planets and their satellites. Some other agencies regarding the atmosphere of the planets, the zodiacal light, the planetoids, Saturn's rings, and comets, are discussed elsewhere; and some only hinted at. In a preliminary treatise like the present, too great a detailed definition would obviously be out of place.

We have glanced at the apparent chaos of original and acquired motions from which, as a skilful potter gives symmetry and beauty to a shapeless mass of clay, the ruling power of the Cosmos has given life and rhythm to our system. The storms have been subdued, and the flames quenched which gave the planets their long baptism of fire, and sorted the materials for their constitution. It is like a fairy tale to trace from the original terrestrial ball of fire the wondrous agencies that selected its material, wrinkled its solidified crust, laid its surface down in layers, kneaded and crushed those layers into mountain chains and immense valleys—gradually to be filled with liquid as the cooling earth allowed the acid vapours and steam to condense as salt water; then to watch the altered eccentricity of the earth's orbit putting into play the physical forces that, during the great glacial periods, alternately covered each hemisphere with a vast ice cap extending far down into temperate regions. Then, again, it is a poem to trace the gradual absorption of the poisonous gas, carbonic acid, and see its carbon combine with other elements and clothe the earth with verdure, whose extent is revealed to us in the vast carboniferous beds of stored energy that we now use to drive our mighty engines. 'Tis indeed a story of wonders to see that verdure partly give place to animal life, and trace the long line of evolution that has culminated in man. But all this I have tried to tell in "The Romance of the Earth." It does not belong to the story of the wondrous stars that is at present being told.

CHAPTER X

METEORIC PHENOMENA

THE ZODIACAL LIGHT—PROBABLY A PORTION OF THE ORIGINAL METEORIC SWARM THAT FORMED THE SOLAR NEBULA. THE PLANETOIDS—PORTIONS OF AN EXPLODED PLANET—PLANETS EASILY BLOWN TO PIECES—PLANETOID ORBITS DISCUSSED. SATURN'S RINGS—A COMPLEX PROBLEM. COMETS—ROTATING MASSES OF PARTICLES ASSOCIATED BY GRAVITATION. THEIR LUMINOSITY INCREASES ON NEARING THE SUN. SPLITTING UP OF SWARMS—PERTURBING ACTION OF PLANETS—SWARMS NOT OF SMALL MASS—COMETS TAILS DUE TO ELECTRIC INDUCTION.

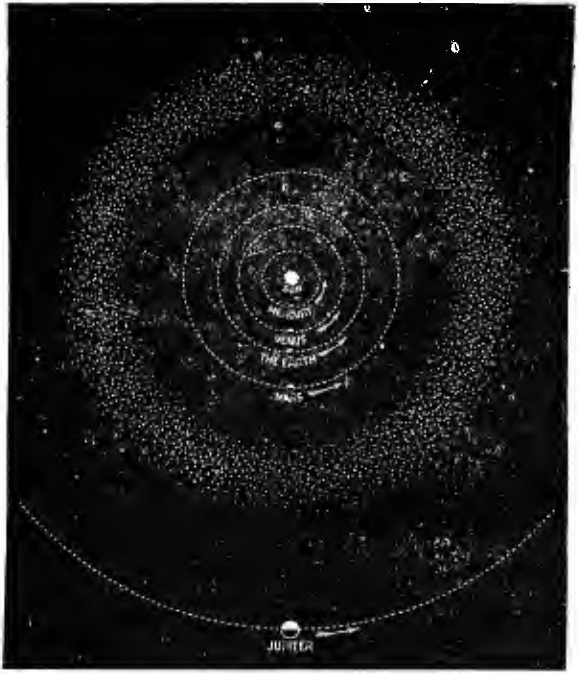
The zodiacal light is a large lenticular or bun-shaped mass of matter, the medial section of which is coincident with the plane of the sun's equator. It extends to a distance almost as far as the earth's orbit, and reaches, in an axial direction, considerably beyond the body of the sun. The zodiacal light is probably a portion of the original meteoric swarm that constituted a large part of the solar nebula,—the smaller bodies revolving in the outer regions of the nebula,—and consequently this cosmic dust did not suffer such retardation as to be absorbed into the general body of the sun, the velocity being sufficient to keep the particles in orbits about the sun.

The whole of the material constituting this vast appendage to the sun is probably composed of independent masses, varying in weight from tons to ounces, and in all probability they are revolving in the same direction as the sun, that is, if they are made up of the original material of the sun. If on the other hand, as some astronomers suggest, they have been brought into the system by being swept from comets in some such way as the meteoric swarms that occasionally pass through the earth's atmosphere have been, then their direction about the sun would be retrograde as well as direct. But if they were thus swept from comets, and consisted solely of meteoric swarms that passed into our system, there seems to be no good reason why they should lie chiefly in the plane of the sun's equator. One sees no reason why they should not be situated in all directions equally about the sun. Therefore from their equatorial position they are probably a portion of the original bun-shaped nebula, or meteoric swarm, that gave rise, by contraction, to the sun itself.

It is probable that some of these small bodies do actually revolve in different directions, for we have reasons to suppose that occasionally collisions of considerable masses occur among these meteors. Such was probably the case in the excessively brilliant light that was seen some years ago and was accompanied by a violent magnetic all storm over the world, and was followed by magnificent displays of the Aurora Borealis the evening afterwards.

Possibly it is the light reflected from this dust swarm that surrounds the sun, that is the cause of the corona seen during a total eclipse, because by the study of a large number of drawings of the corona, there can be but little doubt that it extends much further equatorially than it does axially. If this be so then the sun spots are also in some way related to this zodiac light. This is suggested by the fact that when an eclipse of the sun is seen during a maximum sun spot period, there is a much greater equality in the distribution of the luminosity around the sun. If it is true that in some way or other the corona is due to the zodiacal light, then it is also connected with the sun spot period. Possibly the bat's wing form of the corona as seen at times on both sides of the sun in the equatorial direction, may be due to some order in the orbits of many of these meteors, as we have order in the meteors that constitute Saturn's Rings.

THE POSITION OF THE PLANETOIDS.



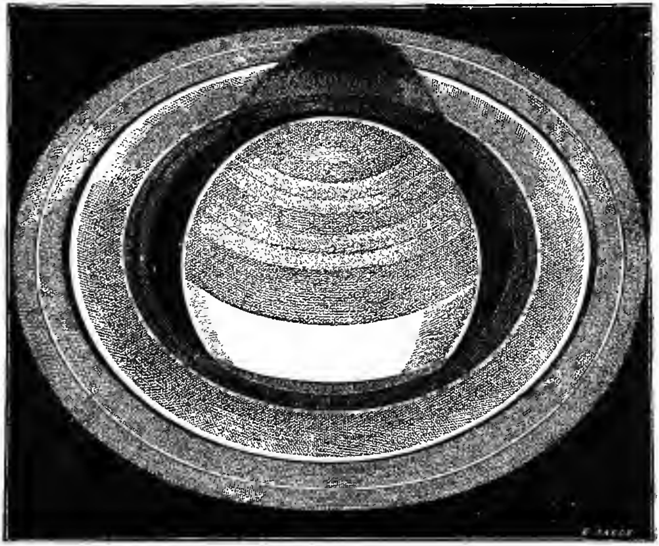
Although I thus believe the zodiacal light to be a portion of the original meteoric matter of the solar system, I cannot believe that this is the case with the planetoids, or with Saturn's Rings. The resistance of the contracting nebula in which they must have been revolving seems to me to render the retention of the planetoids an impossibility, and I cannot but think that Olbers, the original discoverer of the planetoids Pallas and Vesta, was right in his suggestion that these bodies are portions of an exploded planet.

A planet may so easily be blown to pieces. It is probable that the average velocity of bodies at impact is some hundreds of miles a second. With such a velocity the gas produced would have an expansive force that would possess at least from 10 to 50 thousand times the explosive power of an equal mass of dynamite. Consequently were a body of sufficient mass, and endowed with anything like these velocities, to plunge into a planet, the pressure produced would be such that the planet would inevitably be blown to pieces.

Now it has been assumed that if a planet were blown to pieces, the spot where it exploded would be a spot through which the orbits of the bodies would all pass, consequently the idea that they are parts of an exploded planet has been given up. But two circumstances at least, and there are probably others, should be taken into consideration, before we come to this conclusion, and these together seem to render the idea untenable that there would remain a common point for the many orbits. If the explosion were instantaneous and the pressure acted equally in all directions, it would be true of the pieces on their first return, but gradually it would be less true because of the extraordinary perturbations that would be exercised upon the orbits of the various fragments. It is quite clear that in the case of an explosion with the force acting in all directions, all those particles that are on the advanced side of the planet would be accelerated, and those parts that are at the back of the planet's motion would be retarded, whilst those particles at the side would be sent off in such directions as would change the plane of the orbits altogether. Thus those sent away in front would be in the plane of the orbit and would travel quicker, and those sent away behind would be also in the plane of the orbit, but slower. Therefore there would be very different orbits, even in the case of those of the exploded particles that still remained in the original plane of the orbit of the planet; but the rest that were sent in all directions, would be in all azimuths. Now it is known that perturbations are sufficient to alter the eccentricity of the earth fully twelve millions of miles, and it is extremely probable that the perturbing influence of Jupiter upon these much nearer bodies, would alter their curves to a very much greater extent, and consequently the perturbations would entirely prevent the possibility of a common point of intersection of the exploded particles. Although the perturbations may be cyclic, yet the cycle would be such that we could not possibly trace the identity of the position where the explosion occurred.

If the explosion occurred, the body that plunged into the mass of the other body, and produced the explosion, would not effect the whole of its destructive work in a single spot, but the effect of the explosion would be travelling partly with the planet and partly in the direction of the body itself. Nor would the pressure be over instanteously. The pressure would be carrying the bodies, and be acting upon them for some time, and it must be remembered that every agency that takes a definite time only leaves an established orbit when that agency has ceased to act. The orbits of the particles are influenced by their own motion and the sun's attraction alone. These two agencies alone suffice, in my estimation, to prevent anything like an approximate position being found in the orbits of the several fragments that would correspond with the position of the original explosion.

THE PLANET SATURN AND ITS RINGS.



Exactly the same argument applies to Saturn's Rings, which in the same way consist of particles associated by gravitation, revolving in orbits around Saturn, and which, in all probability were once a moon that has been blown to pieces by an explosion.

In the first place, when originally formed, the rings would have a very different appearance from that they now present. They would seem to radiate from a position that was near the area over which the explosive force exercised itself, and this would be a roughly radial position from which the orbits would spread in every direction, giving rise, as it were, to a double plume that would meet on the opposite side of the planet. A number of agencies would tend to convert this irregular motion into a plane. The minute particles into which the possibly molten mass was blown, would be constantly impinging on one another, as they passed the plane of the original orbit, and would tend to bring them into that orbit.

In the same way the impacts would tend to make the orbits of each of the bodies more and more circular. There would be greater resistance at perihelion distance than at aphelion, because perihelion distance would, to a large extent, be the position of the original explosion.

All the particles that have their velocity accelerated would be sent further from Saturn, and those that had it diminished would tend to plunge upon the surface of Saturn, so that it would be chiefly those that had an outward direction that would be persistent, and hence those particles that were driven outwards on coming into the old position, would suffer retardation, and this retardation at perihelion would lessen aphelion distance, and would actually tend to make the path of the orbit more and more circular. There are still further agencies at work in the perturbations of the other moons, but these are of too complex a character to discuss here.

COMETS

Comets are almost certainly dust swarms, and dust swarms, as we have seen, may be produced in a number of ways by collision. The collision of whirling coalescence of two small bodies would dissipate the lighter gas, and the diffused material would become an orbitally connected dust swarm, and the same may be still more frequently the case with partial impact. In fact, all that applies to the origin of star clusters (see Chapter

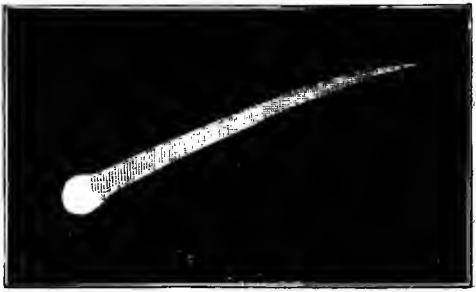
VII) applies also to the formation of a dust swarm, but on a smaller scale.

Possibly, besides these dust swarms visiting our system, there may be meteoric bodies having masses much greater than these dust swarms, but the fact is these masses would almost inevitably escape observation, whereas a dust swarm produces a series of phenomena that causes it to be easily detected.

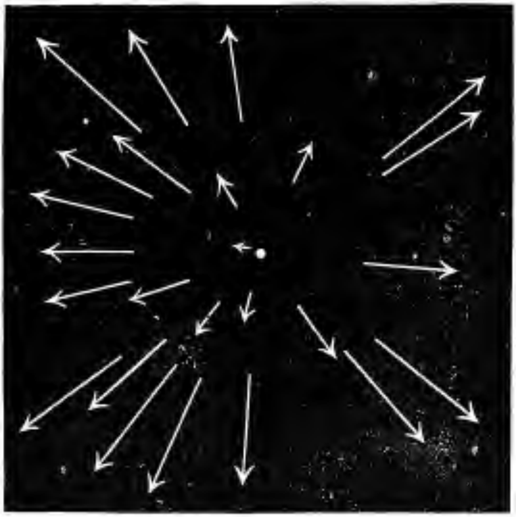
A comet then is probably a rotating mass of particles of various dimensions associated by gravitation, and as a rule in a whirl of which the motions of most of the constitutients are roughly in one direction.

Such a swarm, coming into the solar system, even at considerable distance from the sun, must have the motion of its constituents very much perturbed, and this perturbation would become greater and greater as it approached the sun. The perturbation would occasion collisions, and these collisions would in many cases smash the particles to still finer dust and in some cases convert the collided bodies into gas. In either case they would increase the luminosity, the one by increasing the surface of reflection and the other by giving actual self-luminosity. As they approached the sun this action would be increased to a greater and greater extent, and in addition to this the reflected light from the sun would be more and more brilliant. When very near the sun, the disturbing action would be so great that the side of the dust swarm constituting the comet that was nearer the sun, would be swept forward with enormously increased acceleration and the part more remote from the sun would be left behind, so that the comet would be stretched somewhat into a spindle shape. Should this action be very intense the distance of the parts may become so remote from the general body, that the dust swarm would lose its association with them. These portions would then become a train of meteors that may or may not be orbitally connected permanently with the sun, but it would tend to be connected with the sun, owing to the resistance of the gaseous and other matter of the zodiacal light. But if the perturbing action of any great planet had caused the comet to become orbitally connected with the sun, then we should have a train of meteors that would revolve in the comet's train, and the whole comet, if coming very close to the sun, might be swept out into a train of meteors. That this does not happen with all comets, proves that the idea that they are of exceedingly small mass, is untrue, for if they were of exceedingly small mass, no dust swarm could approach anything like near the sun without being swept into a meteoric train.

A Meteor heated by Friction of the Atmosphere and its Volatilized Train.



With anything like a heavy mass of dust, long before the sun is able to tear it to pieces, the sun's perturbing action sets up such an amount of internal disturbance, that the general body of the comet becomes luminous, and doubtless in addition to the two actions of the smashing of the particles and the volatilisation and heating, we have, with the friction of the particles flying past one another, a tremendous evolution of electricity. Now in an investigation, an account of which I contributed to the "Philosophical Magazine" in Dec., 1873, I showed that in certain conditions of excessively high temperature, electrical disturbances have a tendency to cause particles of gas to carry the positive electricity completely away from the body, and therefore, if the body is a bad conductor and of considerable dimensions, it

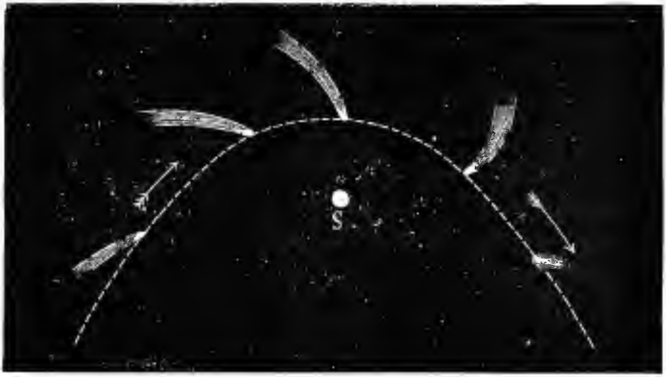


The above diagram illustrates a set of parallel meteors, a part of a train, plunging into our atmosphere. The apparent radial direction is an effect of spherical perspective as is also the increasing lengths of their curves, as they increase in distance from the radial point.

might be left negatively electrified. I should say that the reverse is the case with low temperatures, for at low temperatures the negative electricity escapes more easily than the positive.

At high temperatures the positive electricity escapes from that portion of the system where the electrical disturbances are set up. The consequence is that it is possible that the sun and all heated bodies may be charged with negative electricity. The positive electricity developed in the meteoric swarm, would stream in possibly more or less invisible form from the near portion into the sun, whilst the negative would be repelled from the sun, inducing a path of electrical action directly outwards from the sun. This induced electrical action would take a sensible time to travel the many millions of miles to which the tail of a moderately large comet reaches, so that the form of a comet's tail would not as a rule be straight, but would be curved somwhat into the form of a plume, and as the comet passed nearest to the sun, the radial action would continue, and thus we should have this induced electric phenomenon always being directed from the sun as a centre, while the curvature of the plume would be always backwards, due to the lagging action of the induction, and consequently backwards from the motion of the comet itself. The comet might vary with the nature of the dust swarm which may readily have subordinate centres of motion, and the electrical action that is produced would differ. Doubtless many other agencies come into play in the production of the luminous plume of the comet, but one thing may be taken as being certain, and that is, that it is not in any way materially connected with the comet itself any more than

Diagram Illustrating the Path of a Comet.

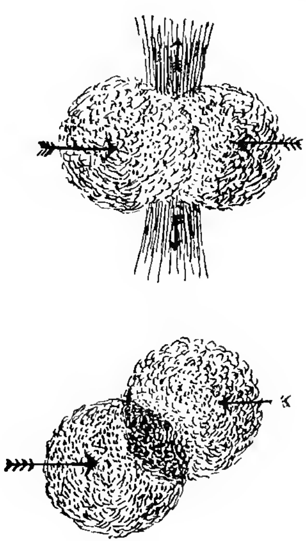


The dotted line represents the orbit of a comet. The diagram shows the radial direction of the tail from the sun, and the retardation of its distant part into a curve.

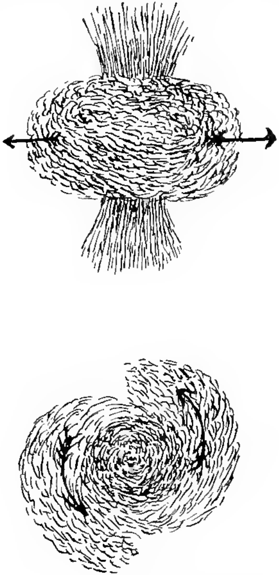
the motes lit up by the beam of a revolving searchlight belong to the searchlight. The tail of a comet is directly a phenomenon of the ether, and possibly indirectly produces illumination of the metoric dust that in all probability exists not merely as far as the earth's orbit, but to a greater or less extent in the whole of the solar system, if not in the whole of space.

The whole of the phenomena of the zodiacal light, the planetoids, Saturn's Rings, meteoric swarms and comets, show in a marked manner the dustiness of space, and give us reason to accept the great Struve's conclusion that the intensity of light coming from vast distances, diminishes more rapidly than inversely as the square of the distance, and if this is the case, we are to a large extent justified in the conclusions we shall come to and discuss in Chapter XIII on the Immortality of the Cosmos, that radiant energy is ultimately absorbed by matter in space.

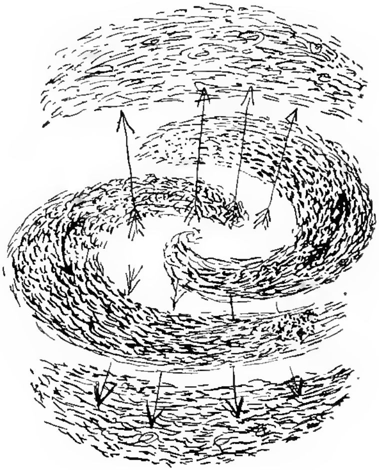
DIAGRAM ILLUSTRATING THE EVOLUTION OF THE GALACTIC SYSTEM.



1 and 2.



3 and 4.



5.

Figs. 1 and 2 represent plan and elevation of cosmic systems coming into impact.
" 3 4 " " " " " in which the impact has advanced to a state of a whirling coalescence.
In 1 , 3 is seen axial extrusion expelling matter perpendicularly to the plane of the whirl.
" 5 is an oblique representation of the two polar caps of nebulæ and the double spiral of stars and other matter forming the Milky Way, tilted toward us..

CHAPTER XI

THE VISIBLE UNIVERSE

STELLAR DISTANCES—HOW THEY ARE MEASURED—TRIGONOMETRY—LIGHT YEARS. THE NEAREST FIXED STAR FOUR LIGHT YEARS DISTANT. IMMENSE SIZE AND NUMBER OF THE STARS. KINDS OF STARS—TEMPORARY—VARIABLE—DOUBLE—MULTIPLE. NEBULÆ—THE MILKY WAY AND ITS POLES. MANY KINDS OF NEBULÆ. THE UNIVERSE THE RESULT OF IMPACT. DISTRIBUTION OF STARS IN SPACE—ORDER IN THE UNIVERSE. CORRESPONDENCE OF FACTS WITH THE THEORY.

> Twinkle, twinkle, little star :
> How I wonder what you are !

Thus runs the old rhyme ; and, now that we know so much about the stars, our wonder is still greater, although of another kind. We are amazed at the marvels unfolded to us, at the majesty of the creation and the vastness of the scale upon which it is built. The distances of the stars from us, and from each other, are so enormous, that double stars, which, a powerful telescope will not divide, when examined by the spectroscope are found to be revolving around each other in orbits that would take an express train hundreds of years to traverse. How are these distances measured? By a property of the triangle. Upon the same base, and upon the same side of it, there cannot be two triangles that have their sides which are terminated in one extremity of the base equal to one another, and likewise those which are terminated in the other extremity, equal to one another (Euclid, Book I, proposition vii.)—by which the old Greek means if the sides of a triangle are stiff, you cannot alter its shape. You may carefully make a five-barred gate, and nail it strongly; but unless you put a diagonal, the gate will sag. The diagonal ties it into two triangles and then it is rigid. So if we have a base line and a distant point, the distance to the point from each end of the line, and the angles the point subtends to the line, are rigidly fixed. Therefore, if we know the length of the lines, we can calculate the angles; and if we know the base, and the angles at its ends, we can calculate the distances. The art of doing this is called trigonometry. So accurate is this triangle method of measurement that surveys of hundreds of miles are often but a few feet out.

This is how we measure astronomical distances. A base line on the earth is measured, and a point on the moon's surface chosen; and by the length of the line and the angles at its ends, we can measure the moon's distance. By a somewhat more complex process, taking advantage of the passage of Venus across the sun's disc, we can measure the distance of the sun. But we can check our solar measurement. By experiment we can determine the speed of light: it is over 186,000 miles a second, about ten million times as fast as the quickest express train. By the eclipses of the satellites of the planets we can tell how long light takes to travel from the sun; and thus, by two methods, we get the distance of the sun and the size of the earth's orbit. Of course, the orbit is an ellipse and does not measure the same in all parts. To measure the distance of the stars we use the earth's orbit as a base line. It is over a hundred and eighty millions of miles in diameter At intervals of six months, the angle a star makes is measured. The angle is so small that only the most accurate workers and the most gigantic and exquisite instruments are able to detect any difference. But year by year the observations are compared and defects are eliminated, until at length there is considerable certainty as to the distance. And what a revelation it is! It would take the swiftest express train forty millions of years to get to the nearest star. It takes light over four years to travel from it to the earth. This star, Alpha Centauri, is not seen in England. It is the brightest star of the constellation Centaur.

The stars move, and by their distances we can calculate their speed across the line of vision. But, wonderful to relate, without knowing their distances, we can calculate their speed in the line of vision by means of the spectroscope; and the revelations of the spectroscope only confirm the calculations from telescopic observation. If light takes over four years to come from the nearest star, how long does it take from the most distant? Probably thousands of years. As far as I can judge by the data available, the huge dead suns that in 1892 gave us the marvellous Nova Aurigæ probably crashed through each other before the battle of Crécy was fought. Then, for hundreds on hundreds of years, the message of the vibrating atoms carved the ether into ripples that told system after system of the stupendous phenomenon which had occurred; then the vibrations reached the earth just in time to be deciphered by astronomers. Had the message come a few years before, it would have fallen on uninstructed senses, and would have been quite lost to humankind. Unfortunately, although the senses were trained the intellect was not. The proverb, "The eye is blind when the mind does not see," is intensely true of telescopic observation. Had the observers been aware that a new temporary star must consist of three bodies, as I had shown by reasoning, and illustrated by diagrams nearly a score of years ago, the whole life history of such stars would probably be known to us now. Vogel's observing power is wonderful; whilst other observers suspected the existence of the broad middle band which told of the brilliant grazed-off mass, he clearly identified it, and even measured its velocity in space. In the cause of science, it is to be hoped that the intellectual inhospitality which has so long closed the doors of science to the theory of partial impact may have passed before any other brilliant temporary star adds lustre to our heavens.

Such, then, are the distances of the stars; what of their size? A million, ten millions, hundreds of millions of times the volume of the earth are common dimensions. Thousands and tens of thousands, perchance hundreds of thousands of millions of times the volume of the earth some of them seem to be. I estimated that those two dark clashing orbs that impacted in case of Nova Aurigæ were respectively four thousand and eight thousand times the mass of the sun. It is no use to try to picture these sizes; we simply do not understand them. We can calculate them perfectly, as we can calculate the heat produced by impact; but what is the use to say it is a hundred thousand times as hot as a blast furnace? Our intelligence does not reach such intensities any more than it does such volumes, such speeds or such numbers. Think of it! Over a hundred million suns in our single universe, besides nebulæ of all kinds, star clusters and meteoric swarms! We know they all exist, but to conceive their greatness is beyond us altogether.

The stars then are suns, in absolutely inconceivable numbers, spread chiefly in a giant ring, called the Milky Way, or Galaxy. In this same ring are all kinds of marvels besides the stars. There are gigantic cloud-like irregular masses, such as the great nebulæ of Orion; also, stupendous disc-looking masses, called planetary nebulæ, which, Herschel says, are shells of gas so gigantic that our solar system might be placed edge on seven times within some of them. Then there are temporary stars—stars that flash suddenly into sight, sometimes expanding till they are the brightest bodies in the entire heavens—probably globes of fire as large as the orbit of the earth, that go on expanding into space, and finally disappear. Then variable stars, that sometimes seem to go out for months and then reappear or exhibit periodic differences of luminosity. Mira, the Wonderful, I have suggested to be a giant dark sun that has had a portion struck off, and thus exposed its molten interior. Doubtless every cosmic body of gigantic dimensions is hot-centered. The tremendous impact no doubt set Mira spinning; and as it goes on rotating it turns alternately its brilliant and dark sides to us. Then we have the so-called twin suns, of which there are many thousands.

There are also triple and quadruple stars; in fact, groups of every kind, up to immense clusters of orbitally associated suns, many of them so exquisitely coloured that in a good telescope they look like a collection of variously-tinted gems. Still there are more marvels in the Milky Way—dead suns, the existence of some of which has been demonstrated. Algol, the Demon star, consists of a dead and a lucid sun, and the spectroscope has measured and weighed that dead sun, has told its velocity and the size of its orbit, and pronounces it almost exactly the size of our own sun. Sir Robert Ball lately expressed the opinion that there may be more dead than luminous suns; I have for years thought this. In our slight glance at the denizens of the Milky Way, what a vast series of gems we behold—

> Studding so thick
> The great galactic ring
> Which forms the crown of God!

Before we can realise the majesty of stellar space we have to make acquaintance with the wondrous aggregation of nebulæ at the poles of the Galaxy; then we may proceed to the mode of stellar evolution.

Let us suppose this Milky Way, this gigantic irregular ring of stars, nebulæ, and a great variety of bodies, to be the rim of a wheel—or better still, imagine it to be a sort of huge double-gerbed Catherine wheel in full display. Our solar system possibly lies somewhere towards the centre of the wheel; while, if we continue the wheel-axis in both directions we come to two stupendous aggregations of gaseous bodies, each cap consisting of thousands on thousands of nebulæ of definite and sometimes exquisitely beautiful form. Taking a celestial globe, conventionally, of course, the solar system occupies the centre; encircling the globe in a broad stream runs the Milky Way; on either side of this stream of stars are comparatively bare belts; then, as we travel towards the poles of the Milky Way, instead of stars, and star-clusters, &c., we come upon nebulæ. Thicker and thicker swarm the nebulæ as we travel onward; most of them roughly spherical in form, altogether unlike the nebulæ to be found in the Milky Way. But spread amongst them are a number of nebulæ of very wonderful shape—double, triple and quadruple nebulæ; nebulæ just coming into impact; nebulæ in impact; nebulæ passing out of impact with a long spindle between them ; every variety of form resulting from the impact of nebulæ. There are spindles; spindles with incipient spirals at the centre, like that of the Lion ; fully developed double spirals ; double spirals with associated nebulæ ; dumb-bell and annular nebulæ, and other forms.

The Milky Way is not without order. We have what Proctor calls star-drift, streams and sprays of stars. I well remember, one clear winter night, chatting on impact with a friend. We were looking up into the heavens, and I noticed these wonderful sprays. "Why," I said, "the very universe looks like a case of impact ; these streams of stars seem to be the result of a whirl !" Stream after stream we pointed out to one another. I had very imperfect ideas of the universe then ; Herschel's old cloven-disc theory was in my mind, and this notion did not fit well at all. I went to Newcomen's "Astronomy," and soon saw I must reconstruct my ideas. Then Proctor's wonderful book, "The Universe," fell into my hands. As I studied it, I saw more and more clearly the marvellous coincidence between the universe as Proctor's great observing power had pictured it, and the result that would be produced by the grazing but coalescent impact of two previously existing universes. It was clear that a rough ring of double spiral character, with sprays and streams of stars, must ensue. It was clear that such an impact must cover the poles with gaseous matter that in time, by the passage of bodies through it, must become nebulæ and nebulous stars.

All irregularities in gravitating groups tend to increase themselves; thus, out of diffused gas grows up cosmic dust; from cosmic dust comes star clusters, or solar systems, according to circumstance. Yesterday, according to the swing of eternity's pendulum, the universe as we know it did not exist. Perhaps we should say our universe; for, though the word in its original meaning applies to the entire contents of all space, it has come to be associated with the galactic system only; there being much reason to believe in the existence of other corresponding systems, the collection of all these universes making up the infinite cosmos. The thought capacity of the human brain is marvellous, but finite; we speak of the infinite —of the eternal—but we cannot conceive them. We know what time, and space, and matter, and energy are; of their whence and of their whither we cannot know. We look, as it were, through a circular tunnel, in which the future is a repetition of the past; what we see is simply one phase of an eternal rhythm. But whence came our universe? And what existed before it was? Does the curve wherein we dwell permit reply to these tremendous questions? I believe it does. With form so definite and arrangements so orderly, we may trace some history of the past and some promise of the future.

Space is probably very imperfectly filled. In the distribution of matter our universe is comparatively crowded; yet think of the emptinesses within our solar system, and of the distance between it and the nearest star! Gravitation tends to clear space of matter and aggregate it; the motion of wandering molecules tends to take them to the empty parts of the Cosmos which gravitation has drained, again to occupy them, and again to initate the formation of new cosmic systems—perchance huge agglomerations without any kind of arrangement, systems of the first order, as I have called them. I shall offer suggestions regarding these vast shapeless masses in Chapter XIII. Our universe is of a higher evolution; it is full of order and symmetry. The system consists not only of the immense belt of stars—the Milky Way—but also of the two caps of nebulæ which—as depicted on the celestial globe—cover the poles of the galaxy. But let astronomers speak for themselves as to its constitution. Sir J. Herschel, who has studied star distribution more than any other man, says that the mass of stars is generally flat, of small thickness. He also says that the number of stars visible in his telescope in the Milky Way amounts to about eighteen millions, and about two millions in the remainder of the celestial vault. Struve published a list of stars in which he showed that in equal areas there were 4¼ at the poles of the galaxy to 122 in the galaxy itself. Proctor, who discusses the facts very fully, after showing that star clusters essentially belong to the galaxy, and that as we pass from that great circle we go through regular stages of irresolvability to the galactic poles, and there find the nebulæ are completely irresolvable, says:—"I believe that cause may be assumed not unreasonably to be the difference in the circumstances under which the galactic and extragalactic nebulæ have reached their present state." Again, in respect to the nebulæ at the poles of the Milky Way, Proctor shows that every theory of their existence is ridiculous, "unless we concede that the nebulæ belong for the most part to our galactic system." The splendid charts and sketches by Sydney Waters, as well as those of Proctor and Newcombe, show strikingly this most remarkable arrangement.

Sir William Herschel states that any sound theory of the universe must account for the peculiar arrangement of the nebulæ. Proctor, in speaking on grounds of probability, says:— "Where the results are in direct contact, the rich regions for one order corresponding to the poor regions for the others, and *vice versa*, the two orders of objects belong to one system," and again says that he knows of no single reason for supposing these nebulæ to be external galaxies. That they are not external galaxies is proved from the facts recorded by Schmidt, Hind and others, that nebulæ have been observed to vary and disappear, which is clearly impossible with a galaxy like our Milky Way. I will give only one other extract from among a large number. It is from Proctor on "The Universe," and is wholly devoted to demonstrate these conclusions. "The phenomena I have been discussing seem to point to conclusions very different from those which have been usually accepted respecting the visible universe. Instead of separating the stars and nebulæ into distinct systems, or rather of looking on the stellar system as a member of the system of nebulæ, we seem compelled to look on almost every object visible, even in the most powerful telescope, as a portion of one system, which comprises within its range simple, multiple, and clustering stars, irresolvable nebulæ, gaseous bodies of symmetrical and unsymmetrical figure, and in all probability myriads of other forms of matter as yet undetected."

Let us attempt to trace out the evolution of such a system. Let us try to realise how two vast globular systems might plunge through one another, and by a centrifugal motion produced by their opposing onrush, be swung into an irregular ring of double spiral character. The two primitive systems were possibly more compact than our own system is now, although there was probably much irregularity in distribution. There would be suns, nebulæ, star clusters and other systems; but they would probably contain much more helium, neon, argon, hydrogen and other gaseous elements than our galaxy does at present. Whilst the two gigantic masses closed in upon each other during millions of years, impacts between the various nebulæ, the suns and other systems, would be of increasing frequency. The centre of coalescence would thus gradually become gaseous, and the average temperature of this part would steadily increase and produce great pressure. This pressure would tend to expand the gas. Let us try to understand with what result. The two cosmic systems are each moving forward, and are partially in impact, whilst the remainder of each travels on, not, however, parting company, but extending vast distances into space. Yet the increased attraction resulting from coalescence will not permit more than a few suns and other bodies with high original motion to escape altogether. Hence, the leading parts travel in a curve. Thus we should have a universe roughly double spiral in character, hot and condensed in the centre, and tending to a general rotation; whilst all the original motion of suns and systems would tell as factors in the resultant motion. But groups of stars similarly situated would tend to take a common direction, and produce the streams and sprays of stars and the community of motion of adjacent stars that have been pointed out by astronomers as so very characteristic of our universe. The impact producing the universe would not necessarily be in the least degree paroxysmal to any of the outer suns and systems; they would not even tend to be heated; dead suns would remain so, and other suns would lose heat and grow old. But at the centre of the vast system everything would tend to become gas under pressure—pressure acting in all directions, but finding relief most easily axially to the general motion. This outrush would cover the polar regions with wide nebular caps. The motion commences by pressure, but is continued by radial molecular activity, to be gradually stopped by the attraction of the whole cosmic system. But another remarkable principle comes in: The pressure at the centre gradually lessens by the escape of material, yet the remainder is still hot, whilst the central attraction has lessened greatly; consequently, molecular escape may permit every molecule to follow the polar nebulæ, and leave the central mass almost bare of matter.

It is probable that originally the polar caps were of continuous nebular matter, that became aggregated into globular nebulæ by the passage of errant bodies through the gas. Much of this diffused gas may still remain, invisible to the telescope; but possibly to be detected by a very powerful photospectroscope. Proctor, discussing the origin of the polar nebulæ, says: "They may have been formed through the influence of the same principle which makes the centrifugal force near the poles of a rotating globe less than that at the globe's equator,"

It will be observed that both regarding the solar system and the galaxy, coalescent impact of two complex bodies has been suggested. In the case of the galaxy, an axial pressure has been assumed as accounting for the polar nebulæ; yet, in the case of the solar system, no such suggestion has been made. Probably, however, gaseous matter did once so cover the poles of the solar system; but a large number of agencies are at work tending to produce modifications in every occurrence of impact, and it will be for future mathematical physicists to determine where one tendency stops and another begins. It may not be out of place, even in this popular account, to give some mathematical conclusions regarding impact. It is demonstrable that an infinitely diffused nebula, condensing into two solid bodies at infinite distance, has lost half its potential energy: exactly as much energy as is available by their attraction bringing the two bodies into impact; therefore, this attraction, in a complete impact of dense bodies, is only half the energy necessary to make a nebula. Secondly, with a pair of bodies such as the sun, it can be shown that the energy of their attraction is only sufficient to expand them to the sum of their diameters. Hence it will be seen that an ordinary complete impact of suns cannot produce a nebula, while partial impact can do so.

Let us retrace our steps. Two cosmic systems roughly spherical in form, consisting of nebulæ, suns, etc., come into grazing impact and whirl around each other: all the original motion of each system as a whole, and also of all the constituent members, tending to give irregularity to the final result. The parts coming into actual impact are gradually volatilised, and, by the pressure, the gas is projected axially, and covers the poles of the galactic ring with nebulous matter. It would seem probable that the onrush of the stars from each of the original systems would furnish two condensed regions. In accordance with this view, Proctor says:—"The stars of the first six orders are gathered into two definite regions—a northern and southern — so markedly that the distribution of stars within these regions is richer than the distribution over the rest of the heavens in the proportion of five to two."

Does not the constitution of the galaxy, given by astronomers as the result of their observations, agree in a most remarkable manner with that deduced from an assumed grazing coalescence of two previously existing systems? All through our universe the spectroscope reveals identity of matter and community of motion. Observers find a most wonderful contrast of character in different parts of the heavens; yet, they say, the contrasting objects are related. The mode of evolution suggested by a partial impact shows the nature of this relationship; shows why there is community of motion in adjacent stars or star drifts; why there are streams and sprays of stars; shows the origin of the galactic belt, why temporary, variable and double stars, why star clusters and planetary nebulæ are there, whilst other regular nebulæ are mostly at the poles of the ring. Whence comes such amazing correspondence between the constitution of the universe as given by astronomers, and this series of clear deductions from a probable cosmic occurrence? Does it not seem to suggest that, just as natural selection—including sexual and intellectual selection—is the agent of organic evolution, so impact, in its many varieties, is the agent of cosmic evolution? It may be that the theory of impact is indeed what a critic has styled it: "A master-key to the mystery, the greatness, the splendour, the multitudinousness and the variety of the heavens."

CHAPTER XII

NEBULÆ

VARIETY OF NEBULÆ—KINEMATIC DEDUCTIONS OF THEIR BEAUTIFUL GEOMETRIC FORMS—THESE STRUCTURAL NEBULÆ FOUND AT THE POLES OF THE MILKY WAY. EXTRUSION OF MASSES OF DIFFUSED GASES. AGGREGATION OF THESE GASES INTO GLOBULAR NEBULÆ—IMPACTS AMONGST THE NEBULÆ—EXPANDING DOUBLE SPIRALS—DOCTOR ROBERTS' OBSERVATIONS—RING NEBULÆ—FURTHER STUDY NEEDED. THE MAGELLANIC CLOUDS—PROBABLY DETACHED COSMIC SYSTEMS—THEY CONTAIN ALL STAR PHENOMENA. CONSTRUCTION AND DISSIPATION OF SYSTEMS.

Leaving the Milky Way, with its hundreds of millions of blazing suns, its crashing orbs, its multiple stars and its gem-like clusters, we pass through vast spaces of comparative emptiness. Then, as we approach the poles of the galaxy, fresh objects become visible. These are the glowing nebulæ—commonly revealed by the great telescopes of our astromers as spherical masses of luminous cloud. Sometimes they show shapes of exquisite symmetry ; and, as the power of observation increases, so the number of nebulæ showing structure increases also. The forms thus made manifest are very varied : long, delicate spindles; shorter spindles with spirals at their centre; exquisitely perfect double spirals; nebular rings, sometimes with light, gauze-like caps at the poles of the rings. Then, there are double and multiple nebulæ, double nebulæ associated with spindles, and many other combinations; whilst, besides these nebulæ at the poles of the Milky Way, there are the planetary nebulæ and the huge irregular nebulæ of the Milky Way itself.

When I first commenced the study of impact, I thought chiefly of impacting suns—dark or luminous—and of the results of such impacts: temporary, variable, and double stars; planetary nebulæ, and system clusters, Presently I began to think of the mechanism of such impacts; I treated the subject kinematically, as scientists would say. Then grew up ideas of lovely forms—spindles, spirals, rings and all the beautiful forms of the known nebulæ. All at once I thought of the explosion of impact, of the awful outrush of expanding gas that must result from the collision of suns. Oh, the horror of it! All my lovely shapes blown to the four winds! I don't often remember unpleasant things, but writing this recalls that *mauvais quart d'heure.* Then, again, I thought: "But the forms are there, and the mechanism is there to produce the forms. What does it mean?" I asked myself.

All at once the impact of nebulæ occurred to me. The kinematics would be the same, but the outrush nothing to speak of in comparison. I knew where the globular nebulæ were spread in the heavens; but everything of interest I had worked out yet had been in the Milky Way. The planetary nebula were there, and I thought these beautiful nebulæ were there also. Had I made a wrong assumption? I tried to borrow a celestial globe, but failed; then, throwing economy to the winds, I bought one, took the bearing of these celestial flowers, and plotted them. My surmise was right; they were not in the Milky Way, but amongst the globular nebulæ at the poles of the Milky Way.

In all probability, then, impacting stars cannot produce these lovely forms, but impacting nebulæ can; and where the nebulæ are thick—giving us the probability of impact of nebulæ—there we find these forms; and in the Milky Way, where the stars are thick, we find the wonders that may be deduced as resulting from the impact of stars.

Let us now try to imagine the origin of these huge globular nebulæ, and of some of the varieties of forms possible to be produced by their coming into contact with one another. In the chapter on the origin of the visible universe, I have tried to show that at one time both of the galactic polar regions were continuous masses of nebulæ of extreme tenuity.

Any cosmic body that passed through such gas might be entrapped; the heat produced by friction would tend to volatilize it; the heavier molecules of the diffused gas would be attracted towards the body; thus as the body travelled, it might leave an expanding train that would make a cometic nebula, although cometic nebulæ may be formed in other ways. All irregularities in gravitating matter tend to accentuate themselves; hence, the volatilized body gradually attracts nebulous matter about it, and a globular nebula results. Attraction acts everywhere; and, where there is no counteracting agency, it generally welds matter into a sphere. Molecular attraction unites the particles of water into the dew-drop, the form of the transparent liquid tears to pieces the interwoven colours of the sunbeam, and sends them forth in wondrous tinted shreds. Attraction makes the solid earth a sphere, slightly flattened by its own counteracting spinning motion. So attractive action on diffused nebulous matter aggregates it into gigantic roughly-rounded masses, the original motion modifying its form.

Doubtless, all these nebulæ retain some of the motion of the original body that commenced their formation, and are consequently travelling in space. Sometimes they must be in one another's path, whilst their own gravitating force urges them towards one another. Thus they collide. The agencies that apply to the impact of stars apply also to nebulæ, but are much modified.

Herschel compares nebulæ and stars in the following passage from his "Outlines":

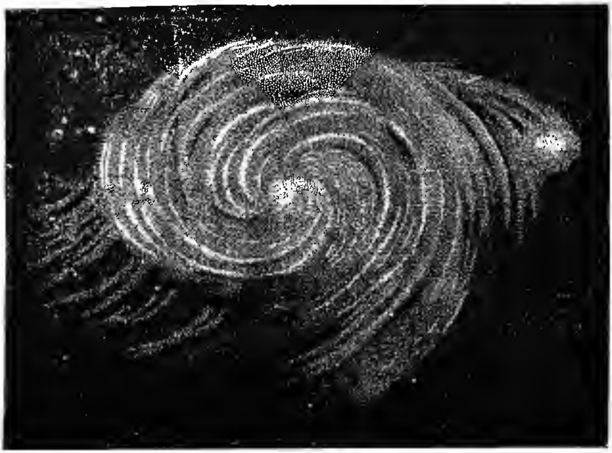
"Double nebulæ occasionally occur, and when such is the case the constituents commonly belong to the class of spherical nebulæ, and are in some instances undoubtedly globular clusters. All the varieties of double stars, in fact, as to distance, position, and relative brightness, have their counterparts in double nebulæ; besides which the varieties of form and gradation of light in the latter afford room for combinations peculiar to this class of objects. Though the conclusive evidence of observed relative motion be yet wanting, and though the vast scale on which such systems are constructed, and the probable extreme slowness of the angular motion, it may continue for ages to be so, yet it is impossible when we cast our eyes upon such objects to doubt their physical connection. The argument drawn from the comparative rarity of the objects, in proportion to the whole extent of the heavens, so cogent in the case of double stars, is infinitely more so in the case of double nebulæ. Nothing more magnificent can be presented to our consideration than such combinations. Their stupendous scale, the multitude of individuals they involve, the perfect symmetry and regularity which many of them present, the utter disregard of complication on thus heaping together system upon system, and construction upon construction, leave us ost in wonder and admiration at the evidence they afford of infinite power and unfathomable design."

I had to ask your patience when we traced the flight of various molecules—but in considering the origin of nebulæ we enter on a new series of motions. We are not considering how the individual atoms sort themselves; we are following the transformation of enormous masses of luminous gas into the beautiful celestial fire flowers that compose the bouquets of the universe.

Our two globular fire clouds are impinging upon one another. The cooler outer portions inter-penetrate, the encounter of the molecules makes them vibrate, and the waves so set up in the ether give us increased luminosity. The nebulæ may move many hundreds of times faster than a rifle ball; yet so enormous are these bodies that the impact may take hundreds, perchance many thousands, of years. As they pass each other the colliding gas forms a luminous spindle between the two nebulæ. Herschel has given us drawings of these vast globes, with spindles between them in all stages of formation. In every case the rare outer atmosphere of each nebula plunges deeply through the other mass, and there is a lack of balanced momentum on either side; so that, as the colliding nebulæ go on their way, trailing the spindle behind, they leave the centre of the spindle in a state of whirl. And so, as each of the ends of the spindle travels after its retreating nebula, gradually the motion of the centre converts it into an expanding double spiral.

The accompanying sketch shows one of these spirals.

Spiral Nebula. (Lord Rosse).



Although the life of a man may not permit him to trace in its full history such a wondrous nebular evolution, yet, so rich is the mighty cosmos that, by means of photography, every stage may be studied simultaneously.

Think of a sensitive photograph plate being presented for many hours to the same object—a plate that, in a thousandth of a second, would photograph a flash of lightning! Imagine this plate fixed in the focus of one of our great light-gathering telescopes, kept by accurate clockwork, following the apparent motion of the nebula; then some idea may be formed of the tremendous power of our modern research!

The great nebula of Andromeda is a spiral; that of the Lion shows the spiral at the centre; then in gradually developing spirals we have that of Pegasus, of Virgo, of Canes Venatici. The "Photographic Annual" for 1895 (pages 234-235) describes Dr. Roberts' discoveries of spiral structure of nebulæ where the visual observation of Lord Rosse and Sir John Herschel entirely failed to discern any such structure. It also describes new spiral nebulæ of great beauty, and other structures never even suspected before in nebulæ. But now comes the part interesting to students of impact. Dr. Roberts, at the meeting of the Royal Astronomical Society in May, 1894, suggests, in explanation of these convolutions, that the nebulæ were formed by streams of meteors which came in contact whilst travelling from opposite quarters of space, the collisions of their margins producing the spiral motion. Again, he says of another nebula: "There is a considerable amount of structure in the nebula, which seems to be assuming the spiral form, as if there had been a collision in one half, which had the effect of closing together the nebulous mass and distorting its form." Thus, although but few astronomers have had the leisure to read any of my papers carefully enough to grasp the deeper principles promulgated in them, there is growing up a belief in the occurrence of Partial Impact, and a superficial appreciation of some of its effects.

But we must leave the spiral nebulæ and pass on to the wonderful ring nebulæ, which, from their analogy to our visible universe, has led us to the most important and far-reaching of all the many subjects the theory covers. Hitherto we have dealt with impacts in which, as a rule, the original bodies have separated after the impact; but, obviously, bodies may plunge so deeply into one another that they never part again, and to a collision of this kind I believe that annular nebulæ owe their existence. It is not to be imagined that a solitary worker in the vast field of impact can think of all the conditions of such complex phenomena; all the agencies set at work by such conflict of forces. Still, I will at least try to tell of some of the forces rendered active by a grazing but almost complete impact of nebulæ.

Instead of two cosmic systems imagine two huge gaseous globes plunging through each other; as they close in from opposite directions we realize that a stupendous whirl must be set up. But the action of axial extrusion is to be traced. Obviously, the mere closing-in of the colliding nebulæ must produce pressure; but compression produces heat, and this in its turn produces more pressure; so that at the centre of the mass there is an enormous expanding force. Where in this whirling mass can it find relief? Certainly not in the directions in which the two nebulæ are closing in upon one another, not in the plane of rotation; but there is no opposing force in the direction of the axis, and in this direction the pressure produces motion. The coalesced bodies are now a kind of huge mortar open at both ends, from which are projected in either direction torrents of gas. Pressure commences the outrush of gas and molecular escape finishes it. Thus is the centre cleared out of the huge, bun-shaped rotating nebula, and it becomes a ring; so that annular nebulæ should for a time be accompanied by a gauze-like material that, seen endways, seems to stretch across the ring; seen edgeways, appears a diffusion in the direction of the axis.

I would urge upon any one who is interested in the evolution of nebulæ to study the various drawings in the light of this account of their genesis. Every grade of the evolution, every variety of collision seems to have its representation. And doubtless should the present be compared with past drawings it may be possible to trace the entire history of the evolution of any form of nebulæ. Do not the possibilities of even a section of the subject seem almost limitless, whilst this much is manifest—the wonder and beauty of the fields of research are as sublime as their expanse is magnificent.

I have tried to give an idea of our universe, very brief and imperfect, but the best I can accomplish without tending to become wearisome. But there are wonders in the heavens that seem not to belong to *our* universe at all ; stars that appear to be visitants from other cosmic systems, perchance there are such systems actually apparent to us, though I suppose the dust of space cuts from our sight most of such systems or universes that probably make up the mighty Cosmos as a whole. The two Magellanic clouds probably are independent systems. Mr. H. C. Russell's remarkable photographs show gigantic spiral structures, with stars, star clusters and every variety of denizen that people our own universe. Is it possible that these are two systems on the way to form, by mutual coalescence, a system of a higher order ? Later on I hope to show how primitive systems may form systems of the first order ; then, by coalescence, systems like our own, of more complex structure and higher order, are formed, partially to dissipate and help to form systems of a lower order again.

Thus in the Cosmos we have birth and death ; construction and dissipation of worlds, solar systems and cosmic systems. Everywhere rhythm and order ; everywhere majesty and law. Of marvel and beauty there is no end, whether it be of the stupendously great or of the infinitesimally minute. We dissect a flower, marvelling at its loveliness. Through a lens we see the structure of its parts, its spirals, its delicate reticulations. With a compound microscope we look into the complexity of its cells. Chemically we pull the cells to pieces and get molecules, we analyse the molecules and sort the constituent atoms. Then we apply the spectroscope, and the atoms reveal themselves in song, and tells us of structures so marvellous that our hearts beat with delight in such adaptation of means to ends, and in recognition of the object of creation.

> Joy is God's index of a rightful act,
> Pain is the signal telling man he errs,
> Dire misery points out deep social wrong.

Was Beethoven at fault when he gave us his weird dissonances? Do not the succeeding phrases ring out the more harmoniously? Shall we blame the Creator for the present dissonant conditions of life? Nay, let us learn the lesson and help to bring about the consonance that is so attainable would we but learn the lesson. But all in good time; well it were we had learned it before. To educate to the careful uses of wondrous fire the burn must be keen and long.

To me, the richness of human life rendered possible by the applications of science is so marvellous that blended with the present paroxysm of hate, I seem to hear the first chords of that sublime music which is, I believe, to be heard in the immediate future of the race. It may be, that still further wrenching dissonances have to be heard for the full appreciation of the grand harmony in store.

We have, glanced at a picture of that portion of the mighty cosmos it is granted us to know about. We have now by deduction but to apply our reasoning power to trace out the remaining portion of a cosmic cycle, and our task is finished. Yet gigantic as is the portion of the creation our enquiry has revealed to us, it is probably but a peep into the infinite.

The theory of impact furnishes a clue to the mystery of cosmic evolution ; by its aid we can trace the stages in the history of the earth, the sun and the universe, and learn that the present is no other than a phase of the eternal. Quotation may here be permitted from a very succinct statement of cosmic evolution on the basis of impact given by the Bradford *Daily Argus* :—

" Shall we have to recast our notions as to the scheme of the universe? It almost seems so. Hitherto it has been an accepted belief that planets and suns and systems are all hastening to one endless death, and the blackness of everlasting night. But from a transplanted Briton in New Zealand—Professor Bickerton, of Canterbury College, Christchurch—comes a newer and more hopeful faith. He has evolved a theory of 'Constructive Impact' which, whilst it offers a plausible explanation of the astronomical problems presented by variable stars, and the new stars which flare into startling brilliance for a few brief astronomical hours, to subside again into obscurity or disappear entirely, also provides for an endless cycle of birth, maturity and death on the part of stars, akin to that which we see around us in organic life. . . . There are other directions in which Professor Bickerton's theory fits into ascertained phenomena, but we have said sufficient to indicate its ingenuity and plausibility. The matter is certainly one which deserves the close attention of astronomers, and it is interesting to the general public as another illustration of the truth underlying the old proverb, that there is nothing new under the sun. Even the sun and the stars may not be new for aught we know, but may have gone through endless cycles, beginning with the nebular condition as chaotic masses of heated gas, and passing through all phases until the condition of passive death—as shown by our moon—is reached, to be again revivified, reduced to the nebular condition again by other stars with which they have collided. There is nothing inherently improbable in the theory, and no substantial reason why the same birth, growth and death of planets should not go on for all eternity. But how immeasurably does the apparent length of eternity extend when æons represented by the birth and life and death and re-birth of solar systems are the ticking of its pendulum?"

We have now but to study the details of the complex series of agencies that seem to permit the possibility of an immortal cosmos, and our task of sketching a picture of the field of constructive impact is finished.

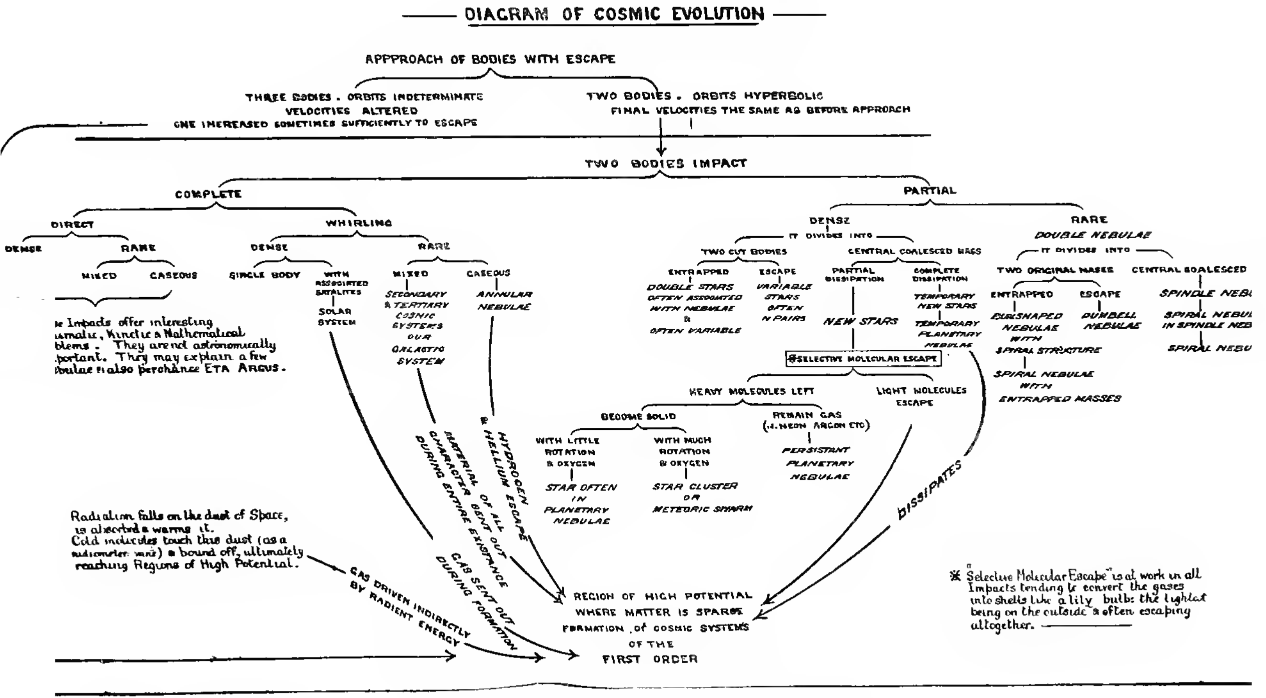


DIAGRAM OF COSMIC EVOLUTION
APPPROACH OF BODIES WITH ESCAPE
THREE BODIES. ORBITS INDETERMINATE
VELOCITIES ALTERED
ONE INCREASED SOMETIMES SUFFICIENTLY TO ESCAPE
TWO BODIES. ORBITS HYPERBOLIC
FINAL VELOCITIES THE SAME AS BEFORE APPROACH
TWO BODIES IMPACT
COMPLETE
DIRECT
DENSE
RARE
MIXED
CASEOUS
WHIRLING
DENSE
SINGLE BODY
WITH ASSOCIATED SATALITES
SOLAR SYSTEM
RARE
MIXED
SECONDARY & TERTIARY COSMIC SYSTEMS OUR GALACTIC SYSTEM
CASEOUS
ANNULAR NEBULAE
PARTIAL
DENSE
IT DIVIDES INTO
TWO CUT BODIES
ENTRAPPED
DOUBLE STARS OFTEN ASSOCIATED WITH NEBULAE & OFTEN VARIABLE
ESCAPE
VARIABLE STARS OFTEN N PAIRS
CENTRAL COALESCED MASS
PARTIAL DISSIPATION
NEW STARS
COMPLETE DISSIPATION
TEMPORARY NEW STARS
TEMPORARY PLANETARY NEBULAE
*SELECTIVE MOLECULAR ESCAPE
HEAVY MOLECULES LEFT
BECOME SOLID
WITH LITTLE ROTATION & OXYGEN
STAR OFTEN IN PLANETARY NEBULAE
WITH MUCH ROTATION & OXYGEN
STAR CLUSTER OR METEORIC SWARM
REMAIN GAS (i.e. NEON ARGON ETC)
PERSISTANT PLANETARY NEBULAE
LIGHT MOLECULES ESCAPE
RARE
DOUBLE NEBULAE
IT DIVIDES INTO
TWO ORIGINAL MASSES
ENTRAPPED
EARSHAPED NEBULAE WITH SPIRAL STRUCTURE
SPIRAL NEBULAE WITH ENTRAPPED MASSES
ESCAPE
DUMBELL NEBULAE
CENTRAL COALESCED
SPINDLE NEB
SPIRAL NEBU IN SPINDLE NEB
SPIRAL NEBU
HYDROGEN & HELLIUM ESCAPE
MATERIAL OF ALL CHARACTER SENT OUT DURING ENTIRE EXISTANCE
GAS SENT OUT DURING FORMATION
GAS DRIVEN INDIRECTLY BY RADIENT ENERGY
DISSIPATES
REGION OF HIGH POTENTIAL WHERE MATTER IS SPARSE FORMATION OF COSMIC SYSTEMS OF THE FIRST ORDER

e Impacts offer interesting
umatic, Kinetic & Mathematical
blems. They are not astronomically
portant. They may explain a few
bulae & also perchance ETA ARGUS.

Radiation falls on the dust of Space,
is absorbed & warms it.
Cold molecules touch this dust (as a
radiometer vane) & bound off, ultimately
reaching Regions of High Potential.

* "Selective Molecular Escape" is at work in all
Impacts tending to convert the gases
into shells like a lily bulb: the lightest
being on the outside & often escaping
altogether.

THIS DIAGRAM REPRESENTS A COMPLETE COSMIC CYCLE.

CHAPTER XIII

THE IMMORTALITY OF THE COSMOS

THE INDESTRUCTIBILITY OF MATTER AND CONSERVATION OF ENERGY. DISSIPATION OF MATTER AND ENERGY—SPACE IS DUSTY—WHY LIGHT IS LOST—ABSORPTION OF RADIANT ENERGY. IT BECOMES VELOCITY OF MOLECULES. HIGH-VELOCITY MATTER PASSES TO WHERE MATTER IS SPARSEST. AGGREGATIVE HIGH POTENTIAL AND GRAVITATION. FORMATION OF A COSMIC SYSTEM. COSMIC EVOLUTION. A CYCLIC PROCESS.

Towards the close of the 18th century Lavoisier's brilliant investigations demonstrated the indestructibility of matter. The great Frenchman proved—by the application of the balance—that nothing material can be lost; that, for instance, fire may cause apparent annihilation; but the atoms which existed before exist still, locked in new combinations. For fifty years this scientific achievement outshone all others, so that immaterial nature passed almost unnoticed, until our English Joule measured the changes of working power—energy we call it. Then another fundamental truth revealed itself. Energy, the imponderable entity of the cosmos—protean as thought—was found to be as indestructible as matter. In the face of this discovery the materialism of science was vanquished for ever.

Then the quantity of this energy—pouring in ceaseless torrent from the sun—was measured, and its origin was investigated. Answers more and more satisfactory were given, and, lastly, it was shown that the heat developed by the contraction of the sun suffices to account for solar radiation for tens of millions of years. Next the questions arose: Where is all this energy speeding to? Even that which falls upon the earth escapes again into outer space. Will the sun send forth all his heat to the dust of infinitude? And, while cooling—with fleeting flashes, as planet after planet falls towards him—what evil fate is in store when he shall have devoured all his children? Will everlasting night encompass the burnt-out orb? It has seemed it must be so—that even collision with another sun will only postpone the period of death. Here let us try to understand Lord Kelvin's great generalisation, called the Dissipation of Energy. The laws of heat suggest that every hot body in the Cosmos is cooling, and, the lost heat will warm the cool bodies until all matter is at one temperature. In like manner the laws of gravitation suggest that all bodies will aggregate into one vast orb, thus reaching a state in which life, as we know it, will be impossible. The universe, probably having begun as diffused gas will end as solid matter.

Is there any mode of escape from this conclusion of universal death? Rankine and Clausius have pointed out possibilities that seem to promise a less melancholy result, but Lord Kelvin has demonstrated their insufficiency. Herbert Spencer—in a magnificent passage in his "First Principles"—shows how impact may revivify; but the method he suggests fails on the score of equivalent energy, and physicists consider it no longer. Possibly there is no single physicist of eminence that does not—willingly or unwillingly—admit the logic of Lord Kelvin's argument. But it may be that—in coming to this belief in universal death—some agency has been overlooked. Is there any means by which low temperature heat may become energy of a higher order? Are there any forces at work to diffuse as well as to concentrate matter? I believe both these questions may be answered affirmatively. The road of reply is definite and unmistakable, but entangled and circuitous; those, however, who will take the trouble to follow it will find it as beautiful and as wondrous as it is complex.

Space is dusty; it is a fog of wandering meteors, errant comets, extinct planets, and dead suns, with free molecules of gas travelling in all directions between the denser matter. Light penetrates this fog for millions upon millions of miles, but in time it is stopped. Thus all radiation may fall upon the dust of space and warm it. Heat is a motion of molecules. Gradually cool a gas, and its molecules lose speed. Let molecules travel from bodies, the attraction of the bodies make the molecules travel slower—in other words, it cools them. Let a slowly moving molecule of hydrogen or helium touch a warm particle of cosmic dust, it will bound off again carrying away the heat, exactly as molecules bound from the blackened heated vane of a radiometer: the heat of the solid body is changed into motion of the molecules, giving the gas a fresh start on its journey.

The farther a molecule is from cosmic matter the slower it travels; it is slowest of all in the most empty parts of space—that is, it lingers longer there than anywhere else. If particles are moving indiscriminately in all directions, and tend to linger anywhere, in that place they will accumulate. I have called this action the aggregating power of high potential. It is a very important principle. To illustrate its nature let us imagine a number of persons moving at the rate of four miles an hour across a field. Let us assume them to be blind and moving quite indiscriminately whilst directly they reach the edge of the field they start back again. Within the field there is a ploughed area, an acre in extent, across which people must move four times as slowly, or at the rate of a mile an hour. If this action goes on indefinitely, it is quite easy to see that there will be on the average four times as many persons within the ploughed area as on an equal area in other parts of the field.

Thus there exists an aggregating tendency the reverse of gravitation, and it also acts in a general way on different kinds of matter. Gravitation tends to select as its especial media heavy atoms, infusible and non-volatile matter, and elements of high affinity. High Potential tends to select light atoms, volatile substances and especially monotomic non-combining elements. The field of the one is where matter is richly distributed. The field of the other where it is rarest. Therefore, freely moving gas tends to accumulate in the empty parts of space, and this gas may originate new universes—cosmic systems of the first order. This is the especial function of such light gases as hydrogen and helium, and perchance of gases lighter still. These minute molecules—these projectiles that selective escape has set free from impacting bodies to travel with incredible velocities—are cosmic pioneers, filling the parts of space left empty by shrinking cosmic systems. There is this difference between these two actions. The cause of gravitation is still an unsolved mystery; on the other hand the aggregating power of high potential is a physical deduction based on a mathematical conceptions, and explains itself.

Hydrogen, which has the lightest known atom, will at any given temperature, have the highest velocity, and in passing out of the cosmic system is the most likely to reach a position of highest potential and should its velocity be more than sufficient to carry it across this space and take it to other cosmic systems, it will move slower and obviously be retarded in the position of highest potential where matter is rarest.

As hydrogen accumulates there, the potential of this portion of space will sink and it will be less difficult for other molecules to reach the place. Of course, any molecule, whether hydrogen or otherwise, that is above the critical velocity of the cosmic system it is leaving, will be able to pass this portion of space, but it will be chiefly hydrogen and helium that will be the first in the field. As these lighter gases accumulate, it will be easier for others to get there and slowly we shall get up to atomic weights corresponding to those of oxygen, nitrogen and neon. This part of space being the position where molecules have a lowest mean velocity will be the coldest part of space and would be coldest of all in its rarest stages. Thus, with this lowest mean velocity oxygen reaches this position sixteen times as hot as hydrogen Hence the temperature of this part of space rises as the gravitating power increases. Ultimately there is a considerable distribution of gaseous matter, in fact, the tendency to aggregate.

will continue until the potential sinks to equality with the rest of space.

Should any high velocity mass plunge through this accumlation, it may become heated to incandescence and bring about a combination of oxygen with the light elementary substances such as boron, lithium, sodium, magnesium, aluminium, carbon and hydrogen. This combustion would give rise to solid and liquid nuclei, which would condense into cosmic dust, and thus it would be possible that this portion of space would become aggregated into dense bodies. This is not possible with the cosmic pioneers, helium, neon, argon, crypton and xenon; for these substances are permanent monatomic non-combining elements remaining permanently gaseous. It is quite possible that at the low temperature of cosmic maximum potential, many of these cosmic pioneers might become liquid, but after material has begun to accumulate the mean temperature of the space would be above the point of liquifaction, and hence these elements are permanently gaseous.

We must remember that not only do molecules travel quickly; cosmic bodies sometimes do so likewise. The star 1830 Groombridge is flying through the universe at the inconceivable speed of two hundred miles a second, whilst if the calculated parallax of Arcturus is correct it has the tremendous velocity of at least 376 miles a second, and Mu Cassiopeiæ shows a velocity of 302 miles a second. Such velocities will probably carry these stars completely through our universe—the chance of their striking another star is exceedingly small—and they will probably travel into those vast gas-filled regions where friction will slowly stop them, heat them, and entrap them.

Thus, gas-filled space is a trap for wandering bodies. Gradually the mutual attraction of the entrapped bodies tends to coalesce them, to condense the gas about them, to diminish the volume and increase the density of these incipient universes. Such masses I call primitive cosmic systems of the first order. They are nebulous aggregations, made up largely of light molecules, continually entrapping bodies made up of heavier molecules. Then, by mutual attraction, these primitive systems collide; and, as a result, selective escape sends some of the light molecules on their journey again, once more to play the part of pioneers, whilst the dense elements aggregate into suns and systems. Continually are the older cosmic systems thus drained of the light gases. But another remarkable principle comes into operation. As already mentioned, three bodies never pass near each other without a permanent relative change of velocity. One may gain speed sufficient to send it out of the universe it belonged to. If two primitive cosmic systems collide and become one, before that one reached its densest state, it would probably—by many agencies—have sent half its matter wandering into outer space, free from its own gravitating force.

It is certain that our universe is not a primitive cosmic system. Its parents were probably not of the first order, but had already collided and attained definite form. The evidence suggests that our universe, as such, is in its infancy; and that probably its parents were of the second order. Possibly, when more is known of its character, later thinkers may be able to speak more decidedly regarding its antecedents.

Has this series of agencies been made clear? If so, the reader can perhaps picture the innumerable wandering molecules set free by cosmic bodies—the dust of space—the movements of radiant energy constantly pouring into space tending to warm that dust; the slowly moving molecules being struck by the vibrations of heated molecules and bounding off again to lose motion by further travel. He will realise the crowding of molecules in those empty high potential spaces where molecules linger, and the gaseous nebula so formed being a trap for wandering bodies set free by the interactions of three bodies; the attraction, the shrinkage, the final coalescence into primitive cosmic systems in which there is practically no definite structure, no recognisable order; then the grazing impact that by the rotation set up would whirl the two huge systems into one, with systematic structure and order. I formerly imagined the Magellanic clouds might be primitive cosmic systems but the wonderful photographs of Mr. Russell have clearly demonstrated such a definite spiral structure that it appears evident they are of a higher order. Their very condensed character also favours this view.

Thus, the theory of dissipation of energy is seen to be a part of a large cyclic process of which partial impact, molecular selective escape and the aggregating power of high potential are also parts and together all declare the Cosmos as a whole to be immortal. A system equally perfect in the marvellous forces within the minutest atom, the complex structure of organic molecular groupings, the infinity of cosmic dimensions, and the eternity of cosmic duration. There is no flaw in the vast design. Atoms clash, combine, and form molecules; and these break up again. Organisms are born and die. Worlds, systems, universes are evolved, play their part, disintegrate and disperse; only to reappear in new and complex relationships. The mighty cosmos remains ever rhythmic in its glorious energies.

Man's mind reels on the brink of the unfathomable when he tries to grasp the mystery even of his own being. Everything impresses him with a feeling of profound humility in his own insignificance. At the same time his surroundings force upon him the most absolute faith in the perfection of the great whole of which he is so minute a part. In contemplating this perfection one feels certain that the present disorder and misery of the world are merely that brief paroxysm of apparent chaos from which order will issue. Is it credible that the evolution of mental power—which enables man to appreciate the superb grandeur of the infinite, which enables him to harness the forces of nature to serve his needs—shall cease with material success. Is it credible that he will remain content to see supine indifference and selfishness destroy all that is lovely in life? Such ideas are incredible. One glimpse of the eternal assures us that the tangled affairs of human life will yet be unravelled fully. May it not be that, just as the burnt child dreads the fire, so the awful effect of the selfishness which has produced the present misery amongst mankind may burn its lesson so deeply as to be ineffaceable in human history? Darwinism clearly shows that pleasurable emotion alone can be persistent, and that pain and misery are indications of decadence. If this be so, what a marvellous gospel of hope is contained in the religion of science! And should the theory of Constructive Impact—this unpractical theory of cosmogony—so awaken intelligence that the perfection of evolutionary methods may be learned, and the lesson acted upon in daily affairs, then such an unpractical theory will prove richer than commerce or business or any of the material achievements so lauded by practical men. When the absolute beauty of the Cosmos is realised by mankind, pain and misery will be suffered only till the alterations that are necessary for their removal can be ascertained; joy will be recognised more and more fully throughout the rolling æons whose infancy we dwell in—joy will be known as the true, the inalienable birthright of humanity.

CHAPTER XIV

DEMONSTRATION OF THE THEORY

DEDUCTIONS AND EVIDENCES

FIVE QUESTIONS TO BE ANSWERED. THE ANSWER TO EACH QUESTION NATURALLY DIVIDES INTO FOUR PARTS, NAMELY, PARTIAL IMPACT, SELECTIVE MOLECULAR ESCAPE, AXIAL EXTRUSION, AND THE AGGREGATE POWER OF POSITIONS OF HIGH POTENTIAL. THE FIVE QUESTIONS IN EACH OF THEIR FOUR SECTIONS ANSWERED IN DETAIL. AFTER WEIGHING THESE ANSWERS SCEPTICISM IMPOSSIBLE.

The preceding chapters have given a general idea of the scope and character of the theory of constructive collision. The conception is simple and not without interest. But the question to be asked is not, is this theory interesting or ingenious? The all important point is, Does this generalisation of cosmic evolution represent the truth?

Answers to the following questions seem to demonstrate it absolutely :—

1. Is Constructive Impact based upon sound deductions?

2. Are there facts available that correspond with the deductions.

3. Is this evidence capable of being explained by any other known theory?

4. Has it shown the power to anticipate the discovery of phenomena?

5. Is it able to guide research?

When we make an attempt to answer these questions, an examination of theory suggests that although it is highly correlated, being not merely continuous but cyclic, yet the scope as well as the character of its thought divides quite naturally into four parts:—

A. A "Partial Impact" of stars or dead suns, producing

(*a*) Temporary stars,
(*b*) Two variable stars,
(*c*) Double stars.

(The fundamental thought of this section is the formation of a third body of unstable character.)

B. "Selective Molecular Escape" accounting for the origin of

(*a*) Planetary nebulæ,

(*b*) Meteoric swarms,

(*c*) Star clusters,

(*d*) Solar systems.

(The fundamental thought of this section is the sorting of atoms by their varying velocity.)

C. "Axial Extrusion," accounting for the form of

(*a*) The Galactic System,

(*b*) The position of the nebulæ at the poles of the Milky Way.

(The fundamental thought in this section is the enormous pressure produced that has no position of relief save in the axis of the whirl of coalescence.)

D. "The Aggregative Power of High Potential:" That is the power of retardation which positions of high potential, exercise upon molecules and other bodies passing through them and the suggestion of the existence of

(*a*) Cosmic Systems or Universes of three orders,

(*b*) The cyclic character of the Cosmos.

The agencies in this action are too complex to be expressed in a phrase.

Let us now attempt to answer the questions enumerated in regard to each of these four sub-divisions.

I

First: Are the deductions true?

PARTIAL IMPACT.

A. Is the idea that a third body will be formed as the result of a grazing impact a reasonable suggestion?

Let us examine it in the supposed case of the impact of two bodies similar to our sun. The bodies will be at a velocity of almost exactly 200 miles a second. To give an idea of the nature of the energy involved, an express train travelling at the rate of a mile a minute would have to have its energy increased by $200^2 \times 60^2$ or 144 million times. But compare the mass of the Sun with that of the train. Obviously, without attempting to calculate, it runs beyond trillions into sextillions. By considering this fact alone, it has not entered into the mind of any scientific thinker of any standing to doubt the possibility of portions being sheared from the colliding masses and coalescing to form a third body.

(*a*) Would this third body be unstable? In other words would the motion of the molecular velocity be sufficient to carry away every impacting particle into space? Oxygen at about 200° absolute, moves a quarter of a mile a second. When it moves a mile a second its temperature is 3,200°. When the molecular velocity is 200 miles a second the temperature will be 128 millions of Centigrade degrees on the absolute scale. At such a temperature everything is dissociated and volatilised, and if only the graze be small enough, it is obvious that every molecule is above the critical velocity. Obviously the mass expands; and obviously, also, it dissipates into space. Consequently a brilliant body is suddenly produced, becoming in a short time supremely brilliant, and then quickly fading away. This is the Temporary Star.

(*b*) As to the two cut bodies, it is clear that there is an unbalanced momentum in the deeper part of the cut. Consequently a portion of the third body will become entangled, and this highly heated matter will produce a scar of greater luminosity than the rest of the body. It is clear also that this entanglement will retard the motion of this side of the body and will give rise to rotation. The stars thus present periodically their heated highly luminous scars to different parts of the heavens, and each body appears as a Variable Star. Hence variable stars should appear in pairs; and although one may lose its variability quicker than the other, some variable stars should still be found in pairs.

(*c*) Is it not certain that the coalesced mass tends to add to the attraction exercised upon each other by the retreating scarred bodies, and that such additional attraction may wed them, and convert them into a physical pair? If before the pair reached aphelion distance the central body has dissipated, is it not also clear that the perihelion distance will be increased? Thus the pair of stars may be orbitally connected; that is, we have a Double Star.

SELECTIVE MOLECULAR ESCAPE.

B. Accepting similarity of state, square root of mean square etc., etc.; the following are recognised laws of Thermo-dynamics:

1. The specific heat of an element varies inversely as its atomic weight.

2. With the same quantity of heat equal masses will be heated in the proportion of their atomic weights: that is an equal mass of oxygen will be 16 times, and lead will be 207 times as hot as hydrogen.

3. At the same temperature, molecular velocity is inversely proportional to the square root of the molecular weight. Hence at the same temperature the molecule of hydrogen moves four times as fast as oxygen; and since the energy of a body varies as the square of the velocity, at the same temperature, hydrogen has sixteen times the tendency to escape that oxygen has, and it escapes with four times the velocity.

Hence it is surely sound to assume that when moving in free space, molecules endowed with a momentum above the critical velocity will tend to sort themselves, and will escape in the inverse order of their atomic weight. This sorting process I have called Selective Molecular Escape.

(*a*) It is obviously likely that in many impacts some molecules will have velocity enough to get away from the mass, while others will not be able to overcome the attraction of gravitation. There will be intermediate molecules that will neither have energy enough to get away, yet will have too great a velocity to be quickly attracted back. In other words, they will approximately reach a position of maximum potential, and will possess no appreciable velocity when in the vicinity of that position. After being for a time approximately at rest, they will slowly acquire a new motion in the direction of the central mass. Clearly it follows that such a set of molecules may form more or less temporarily a hollow shell of gas, or in other words, a Planetary Nebula.

(*b*) A rotating mass of matter that contains in it solid or liquid particles and in which there is no gas to produce retardation, is obviously an orbitally connected mass, but since these particles will be continually crossing one another's paths, there will be impacts and possibly coalescence between the members; and even if the general temperature be high, when there is a considerable quantity of oxygen present, the non-volatility of the oxides formed will tend to cause fusion on impact, and coalescence rather than volatilisation, Hence the rotating mass of non-volatile material becomes converted into a meteoric swarm, possibly of a very high temperature.

(*c*) If it continues to coalesce, such a swarm becomes a star cluster, and ultimately, by the further collision of the masses, tends to become a group of bodies associated around a central sun.

(*d*) Two such systems as these latter coming into whirling collision, would, in the manner already minutely detailed, give rise to some system of free bodies, constituting planets on the outer regions of the original system.

AXIAL EXTRUSION.

C. A case of whirling coalescence of vast cosmic systems, such as the Magellanic Clouds, will be associated at one period of its existence with great pressure in the particular parts that have actually come into collision. A kinematic consideration will show that this pressure can find no path of escape save in both directions along the axis of the whirl. Hence matter will be shot upwards and downwards from this whirl-axis, and may very readily be sent to a very considerable distance. In fact, it is probable that in most cases some of the material will be endowed with a velocity higher than the critical velocity, whilst an immense quantity will reach a position at which the attraction of the mass is very much weakened, and the return journey will be one of extreme slowness. A whirling collision between two such systems will therefore produce a sort of rough double spiral with two polar caps of nebulous matter in a more highly gaseous state than those portions of the systems that have not actually come into direct impact, and thus we have deducibly possible from the theory of constructive impact a state of things resembling the visible universe.

(*a*) Thus there would be to an observer within the whirling systems, a ring of stars all around, consisting of the two parts whirling around each other, such as is the case with the Milky Way and

(*b*) There would also be as a result of the axial pressure gaseous matter extruded from the whirling systems in the form of nebulous caps such as exist at the poles of the Milky Way.

AGGREGATIVE POWER OF POSITIONS OF HIGH POTENTIAL.

D. The reader will have observed that, as we passed onwards from Section *A*, the nature of the deductions increased in complexity, also introducing gradually an increase of speculative ideas into the problem. Yet in no case is there an hypothesis of any new force or new property of matter, the whole of the deductions being absolutely based on scientific fact. Nevertheless the increase in complexity carries with it a certain air of speculativeness. In this section we are treating of the aggregating power of high potential exerted upon bodies originally at a high velocity. This action stands absolutely in contrast with the aggregative power of gravitating masses in trapping bodies of low velocity. Here we trench upon such unworked scientific ground, that although the deduction appears perfectly straight-forward, and by no means difficult to comprehend ; yet it were better that this part of the subject should stand alone. Its final non-acceptance would not in the faintest degree carry with it disproof of the prior propositions.

The farther we get from a cosmic body, the lower will be the average velocity of associated bodies, including elementary molecules. The stupendous velocity that may occasionally be acquired by hydrogen, amounting almost certainly to thousands of miles a second, suggests emphatically, that such a velocity is capable of carrying it beyond the universe ; or in other words as regards the galactic system, hydrogen can attain a velocity above the critical velocity. If there be in space other systems similar to our galactic system, and should hydrogen pass out of one of them, between these systems there will be a position of highest potential with regard to both, and it is there that the hydrogen will move the slowest. Where the hydrogen tends to move slowest, it tends to accumulate. All bodies including molecules that have been sent out of systems and are moving indiscriminately in all directions, will in the same way tend to be retarded in positions of high potential. When the accumulation of hydrogen becomes considerable, it is still in a position of high potential, but its potential is lessened by the accumulations. It was its high original velocity that enabled it to reach a position where the molecules could thus accumulate, and since any other material that will reach this aggregating position must have been originally of high velocity, there is a tendency for this portion of space to contain matter consisting of light atoms and also of such elements that do not easily aggregate. It is not here necessary to recapitulate the argument as to the function of the cosmic pioneers and the trapping action that these elements must possess, but it will be seen on a review of the former chapter that a large set of interacting agencies are at work, that suggest that in this way cosmic systems of a different character to our own galactic system will be formed, and that the collisions of two such primary systems may produce a system somewhat similar to our own.

The essential point to be considered is that there are two modes by which matter can aggregate: the first being that of gravitation by causing attraction of matter towards matter, consisting of dense and non-volatile material; and the second being the fact that bodies of high velocity, consisting chiefly of atoms of light gas, tend to accumulate in the sparsest portions of space, and are thus in a position of maximum potentiality.

This then represents the more important of the series of deductions that give rise to the theory of constructive impact. We now proceed to consider if there are any facts that correspond with these deductions.

II.

CORRESPONDING FACTS.

A. (*a*) In the case of temporary stars, of which over a score have been recorded, most of these stars have been almost at their brightest when first seen. Some few were of extreme brilliancy at first, but others to which attention was directed in their earliest stages, for some days increased in brilliancy—increased enormously. The whole of these stars have rapidly dissipated into space; yet some were of such intensity that it is almost certain that they must have been thousands of times more brilliant than our sun. Very few of these temporary stars have lasted more than a year.

(*b*) The theory suggests that variable stars should be produced at the same time as temporary stars, and that they shall be in pairs. It is a remarkable confirmation of this that Nova Vulpeculæ (Anthelm's Star), of 1670, has, near its position, a known variable star, and a suspected variable. The figures from a small area of the heavens have been given in the chapter of variable stars. The great number of variables that occur in pairs, but too distant from each other to be associated by gravitation, cannot be the result of chance.

(*c*) Many double stars are variable. This fact was pointed out by Struve in an article published in *The Intellectual Observer* for 1862, in which he says definitely that some twenty-three double stars are variable, and he suspected some forty more.

In *Knowledge* for September 1st, 1899, Mr. J. E. Gore points out the variability of some well-known binaries and in a subsequent letter to myself he has added four more to the list. It is also known, as the theory suggests, that both double and variable stars are associated with nebulæ.

B. (*a*) Herschel gives an account of hollow shells of gas as being the only possible explanation of planetary nebulæ. It seems difficult to conceive of any other way in which shells of gas can originate except in the case of the peculiar sorting action of Selective Molecular Escape. Moreover, temporary stars have been known to become planetary nebulæ, and in the case of Nova Aurigæ, Professor Barnard has even succeeded in measuring its apparent disc.

(*b*) That meteoric swarms exist is demonstrated by the phenomena associated with comets, some of which have been torn to pieces by their near approach to the sun, and some pass through the orbit of the earth. The disseminated portions of the comets, when crossing the orbit of the earth, occasionally become visible to us as a swarm of shooting stars, the dust becoming incandescent while passing through our atmosphere.

(*c*) The star clusters exist in such numbers that reference to the facts concerning them that support the deductions need not be made.

(*d*) As regards the solar system there is an extraordinary coincidence between it and the deduced results of the whirling collisions debated so fully in Chapter IX., that it would be waste of time to do more than point to the facts recorded.

C. With regard to the coincident facts connected with the appearance of the Cosmos and the polar caps of nebulæ, I cannot do better than refer the reader to those works on the character of the universe that have been written by Proctor and Gore, and the magnificent charts of Sidney Walters published in the transactions of the Royal Astronomical Society.

D. We have no evidence of the existence of systems of the primary cosmic character suggested by the theory, or that they are in process of formation, but were they forming, and were the formation to reach up to the outposts of our own universe, I cannot see that there is any possible mode by which we could become aware of their existence, unless it be that wonderful spectroscopes may be built that may suggest that such a system is forming, but this in the highest degree is an improbable suggestion.

III.

Is there any satisfactory explanation of temporary stars that is so simple as to have passed into common science? Is there any explanation of the fact that variable stars appear so frequently in pairs; that double stars are frequently variable; that both are often associated with nebulæ? Is there any reason why variable stars are left where temporary stars have before existed? Is there any explanation that gives a coherent account of the origin of planetary nebulæ and why planetary nebulæ should sometimes have stars at their centres and should be where temporary stars have once appeared?

Does any explanation exist as to why the planets nearest the sun should be small and dense, and their axes tip over so as to make large angles with the ecliptic; why the outer planets are large and rare; and why Uranus rotates in a direction the opposite to the other planets?

Has any suggestion yet been made as to why the universe should consist, roughly speaking, of a double spiral or ring of stars, and two polar caps of nebulæ, and why there should be streams and sprays of stars in the system?

In no case do I know of any explanation that fits in with the apparent facts, except the deductions that have been made from the Theory of Constructive Impact.

IV.

Are the deductions of this theory able to anticipate phenomena?

One half of the facts with which the Theory of Constructive Impact is concerned were unknown to me until I had sought for them, in many cases, for years. An immense number of facts, such as that of the existence of pairs of variable stars, the existence of variable stars near where a temporary star had been formerly, and many other points of the theory are, I believe, still unknown to the ordinary astronomer.

The most remarkable of any of these anticipation of facts is the case of Nova Aurigæ. The diagram illustrating the impact of two dead suns facing Chapter III. was first printed in 1879, thirteen years before Nova Aurigæ appeared. The following is a list of predictions made before the year 1880, and verified by actual observations of astronomers since 1892:—

PREDICTIONS. MADE A SCORE OF YEARS AGO.	DEMONSTRATIONS MADE RECENTLY BY ASTRONOMERS.
1.—The theory required that a new star should consist of three bodies.	1.—Shown by the astronomers of Europe and America of Nova Aurigæ.
2.—That two of these bodies should be flying from each other at stupendous velocities.	2.—The velocities measured were 400 and 320 miles per second, respectively.
3.—It predicted that the middle body should be moving slowly.	3.—Vogel's estimate was 23 miles a second.

4.—This middle body should become a planetary nebula.	4.—Several astronomers observed this nebula; Professor Barnard measured its disc.
5.—That there should be fluctuations of light in the two retreating bodies.	5.—One fluctuation was observed and was so striking as to be spoken of as a "re-appearance." Sir Norman Lockyer says it was not the light of the nebula that increased. It must consequently have been, according to prediction, the light of the other bodies.
6.—These three bodies (one being nearly at rest, one flying one way, the other in the opposite direction) must produce a triple lined spectrum.	6.—This was the first well-ascertained fact that so surprised astronomers all over the world. Alfred Taylor, after studying the work of 85 observers, summed up with "there is no doubt of this fact."

7.—The theory required that one of these lines should be bright and broad with indistinct edges, and on this line should be the two lines either bright or dark.	7.—This was the exact character of the spectrum as obtained from a mean of all the observations.
8.—Finally it was predicted that the temporary star should disappear.	8.—And it has done so.

Such are some of the remarkable verified anticipations of Partial Impact. Can many cosmic theories show such results in the very infancy of their acceptance?

V

The last question is, Is the Theory of Constructive Impact likely to guide research?

Reference has already been made to the many facts that have been found only after much searching for them, and that are even now unknown generally to astronomers.

Doubtless had the astronomers of Europe been aware that in Nova Aurigæ they should have looked, in the first place, for the characteristics of a temporary star with its peculiar bright indefined nebulous line; secondly, for two variable stars flying from one another at velocities of hundreds of miles a second; and thirdly, that these two variable stars would show fluctuations of light that would intermix with the light of the temporary star, they might have ascertained by more liberal and careful observation, the detailed curve of light that the phenomena exhibited. They would certainly have known that they had to look for broad bands on the spectrum upon which would be superimposed two other bands, each of which would in all probability have changed from dark lines to luminous ones. Probably more confirmatory evidence of the theory would thus have been forth-coming. Astronomers should now search in the vicinity of every variable star to ascertain if there is not another in its near neighbourhood. They should measure the distance of the present pairs to ascertain if the distance is increasing. They should search the position of every recorded temporary star to ascertain if any variables are near it. They should search in star clusters and ascertain if any of the variables in the clusters are in pairs, and if these pairs are wedded into definite orbits. They should carefully be on the look-out for temporary stars of short duration within these clusters, and especially in those star clusters, or parts of star clusters, where a richness of variable stars seems to suggest that the paroxysms or series of encounters have not yet died down. They should look for nebulæ associated with variable stars, and especially in the case of double stars that are at the present time variable. They should compare the present distances of pairs of variables with earlier measurements, and in the case where the former lists only gives one of the two, they should ascertain if its place has been moved in the direction that tends to increase the distance from the other star.

The forms of the nebulæ should also be compared with older drawings, and great pains should be taken to produce the best possible photographs of all existing nebulæ showing definite structure as contrasted with globular nebulæ. The old pictures should be compared with the new to ascertain how far the spindles, show incipient spirals, and spirals show further development. Double nebulæ should be carefully watched to see if there is a faint spindle lying between the components. The centres of planetary nebulæ should be examined for signs of incipient star clusters and for faint aggregations of light of different charcter to that of the nebula itself. The diameters of the discs should be carefully measured. All double stars should be carefully watched for intensity to ascertain if any considerable number of them should prove to be variable. The variable double stars should further be investigated to ascertain if both the stars are variable, or only one of the constituents These are suggestions of a few of the directions in which the theory of Constructive Impact will be likely to guide research.

In face of the evidence presented, any doubt of the collision of stars is as though a person saw two locomotives up on end and entangled with one another, all the carriages of the train telescoped, death and destruction everywhere, and were to say: "It cannot be a collision. Our system of electric switches renders them impossible. I own it looks like one, but it must clearly be a delusion, for our system of signalling is absolutely perfect. Besides I did not see the collision, and seeing only is believing. You must really seek some other explanation."

Scepticism of stellar impact is as though a man entered a shattered house and said: "It is impossible a shell has exploded here, for there is an armistice."

"But," says someone, "look at the dilapidated house; see the nature of the wounds and smell the gunpowder!"

"Yes! If it were not for the armistice I should certainly think that a shell had exploded, but you see it cannot be so."

"But look at the pieces of iron sticking in the walls, does not that prove it?"

"I see the iron; I admit the evidence is plausible; but we must not forget the armistice."

It is scarcely an exaggeration to say that the evidence in these two similes is not more striking than the evidence of stellar collision. Only had we no such evidence, it is almost certain that there must be collisions, for there is no system of switches and rails to keep stars apart, and no armistice to prevent them colliding; but on the contrary, there are actually mutual attractions pulling them like mighty magnets towards each other.

So when we see space strewn with star wreckage, it seems incredible that anyone can think stars do not collide. We stand in the presence of the actual facts, and we are forced to believe in their encounters.

CHAPTER XV

SYNOPTIC STATEMENT OF THE PRINCIPLES AND PHENOMENA OF COSMIC IMPACT: PREPARED FOR THE USE OF SCIENTIFIC MEN AND SOCIETIES.

STELLAR COLLISION—PARTIAL IMPACT—NEW STARS AND PLANETARY NEBULÆ — SELECTIVE MOLECULAR ESCAPE—FORMATION OF STAR-CLUSTERS AND METEORIC SWARMS—COMETS—VARIABLE STARS—DOUBLE STARS—NEBULÆ—ORIGIN OF THE GALACTIC UNIVERSE—THE SOLAR SYSTEM—MATHEMATICAL CONDITIONS OF THE FORMATION OF NEBULÆ—THE COSMOS POSSIBLY IMMORTAL—SEQUENCE OF AGENCIES—LIST OF PAPERS IN THE TRANSACTIONS OF THE NEW ZEALAND INSTITUTE.

1. The new photographic charts have demonstrated that there are over a hundred million bright stars in the Milky Way.

2. The companion of Sirius and the dark component of Algol prove the existence of dead suns. These are possibly very numerous. Sir Robert Ball thinks them more numerous than luminous

ones: for other theoretical reasons than his I believe him to be right.

3. Stars have an independent velocity or proper motion of about ten miles a second upon an average. Recent spectroscopic observations seem to suggest a slightly higher velocity than this.

4. This motion is apparently without much order. It will alter the relative distance of stars, and may bring them near each other, and possibly into impact.

5. If they are brought near each other their mutual attraction will alter their velocity, and curve their courses into hyperbolic orbits. If they do not graze they will ultimately again attain their original proper motion.

6. When stars are very near each other their attraction will cause them to be distorted into an egg-shape.

7. The tendency to collision will therefore be increased by their mutual attraction in these two ways, for it will cause them (1) to curve their courses, (2) to be distorted when very near each other. The chances of collision will thereby be made one hundred times greater on an average. In the case of two such bodies as our

sun the chances of collision would be about one thousand times greater.

8. All impacts brought about in this way by deflection will be of a grazing character; consequently nearly all stellar collisions of approximately equal bodies will be of a grazing character.

9. The average velocity of stars at impact will be hundreds of miles a second, and in many cases thousands. The average "proper motion" will not appreciably affect the final velocity. Thus a proper motion of ten miles will add less than half a mile a second to a colliding velocity (velocity acquired by attraction) of one hundred miles a second.

10. A mere graze of the atmospheres of stars obviously will not cause them to coalesce, nor will a slight graze of the stars themselves. As a mean result, when more than a third of each of two equal bodies collide, coalescence will ensue, but this will depend on the original proper motion. Were nine-tenths of 1830 Groombridge to collide with a similar star the remaining tenth would not be stopped in its course; it would pass on in space, the bulk of the two stars temporarily coalescing and then dissipating into space.

11. The effect of the collision will be to intensely heat the colliding parts. Were the surface of the sun composed of oxygen the temperature produced by a slight graze would be about 120,000,000 centigrade.

PARTIAL IMPACT.

12. The heating effect of a graze of two stars, of two star-clusters, or of two nebulæ, or even of a star plunging through a star-cluster, will not appreciably extend to the parts not colliding. To emphasize this fact such impacts have been called "partial."

13. "Partial impacts" of stars generally result in the formation of three bodies. The fraction of each star, lying in the path of the other, which actually collides, and whose momentum will be nearly or quite destroyed, will be cut off from the rest of the star; they will coalesce and remain behind, whilst the two cut stars pass on in space.

14. Partial impacts of a third of two equal stars having considerable original proper motion would make of the two impacting orbs three equal bodies: two of them would travel on in space in opposite directions; the third would

revolve and dissipate without any motion of translation. If there had been no proper motion the three bodies would have coalesced into a whirling mass. If less than a third be cut off from each, the two bodies become three bodies orbitally connected.

15. The temperature produced by an impact depends on the velocity destroyed and on the chemical constitution of the colliding bodies. High velocities and heavy molecules both tend to produce high temperatures. Consequently the temperature does not depend upon the amount of the graze. Were one-tenth or one-hundredth grazed off the impacting stars, the temperature of the coalesced part would be the same.

16. Although the temperature will be the same, the gravitating power of the coalesced part will depend upon the mass and volume of that part; it will increase as the mass increases, and diminish as the volume increases if the mass remains constant.

17. There is a speed called the "critical velocity" at which projectiles would permanently leave cosmic bodies; this velocity is seven miles a second for the earth and 378 miles a second for the sun.

18. Heat is molecular motion. In a small graze of any given pair of stars the molecules will have the same velocity as in a large graze, but the gravitating force holding the bodies together will be different. In a large graze the body may be stable, the velocity of the molecules not overcoming the attraction of gravitation; in a small graze the body will expand indefinitely in consequence of the small attractive power of the coalesced mass, and every expanding particle will have so high a velocity that it will in general become an independent wanderer in space, the velocity of the molecules being above the critical velocity of the mass. Consequently space will be spread with free molecules.

NEW STARS AND PLANETARY NEBULÆ.

19. The mass of gas produced by such an impact will obviously expand temporarily into a hollow shell of gas. Herschel tells us this is the condition of planetary nebulæ.

20 A partial impact of stars will therefore generally produce in less than an hour an intensely heated body that will expand enormously for a time, without much diminution of heat.

It will consequently become very bright indeed, after that it will continue to expand with diminishing intensity until it becomes a planetary nebula, and will then often disappear by the molecules dissipating completely into space.

21. Therefore in this time a new star has been born that increases in intensity until the general parallelism of motion of the molecules causes a lessening number of impacts between the molecules. As Sir William Crookes' experiments in radiant matter prove that molecules only radiate immediately after encounters, the luminosity will diminish, and will go on diminishing until the body disappears. In special cases the planetary nebula may be fairly permanent. In other cases a permanent star may appear in the centre of the nebula.

22. The graze occupies less than an hour and as with bodies of equal density the velocity acquired is proportional to the diameter, all grazing impacts of true stars or dead suns will occupy about one hour.

23. The molecules on the far side of the nebula (or third body formed by the two colliding stars) will be retreating from us; those on the near side will be advancing towards us.

The spectrum of such a body will consequently be crossed by broad bright bands with a maximum in the centre and gradually dying imperceptibly away. If this body has any motion in space, as it probably will have when the two colliding stars are unequal, the line of maximum intensity, though in the centre of the band, may be displaced from its true position.

24. Soon after impact the escaping molecular velocity will be greater than the motion of recession of the two cut stars, consequently the displaced lines of these bodies will be on either side of the centre of the broad band, but on its surface.

SELECTIVE MOLECULAR ESCAPE.

25. Immediately after the impact the temperature of different kinds of molecules will be very different from one another. Were the two colliding spheres composed of oxygen, they would be sixteen times as hot as if they were similar spheres of hydrogen. The temperature at impact will be proportional to the atomic weight. In a sphere of mixed elements these inequalities of temperature would quickly equalize themselves. When this was the case the hydrogen

would be moving four times as fast as the oxygen. The velocities would vary inversely as the square root of the atomic weights. Whilst their escaping *energy* will be inversely as their atomic weight, that is hydrogen will have sixteen times the chance of escape that oxygen has.

26. This difference of velocity will tend to sort the molecules into layers like those of a lily bulb. The hydrogen on the outside will be followed by helium, lithium and other elements in the order of their atomic weights.

27. If there are elements lighter than hydrogen or if as Prof. J. J. Thomson suggests there be entities smaller than atoms, these will, of course, precede hydrogen. In my lectures and papers on this subject I have called this action "selective molecular escape."

28. Space will be thickly spread with free molecules of the lightest elements. This fact is important: it is one of the counteracting agencies that prevent the theory of the dissipation of energy being of cosmic application.

29. A telescopic view of a new planetary nebula produced by a partial impact, if seen through a prism, should give a series of discs of

diameters diminishing with increase of atomic weight in its component elements.

30. This fact, taken in conjunction with the broadening of the lines into bands, will enable us to calculate the distance of such a body. It is possible, however, that the parallelism of the motion of the foremost molecules may prevent encounters ; hence this layer of gas may not be luminous.

FORMATION OF STAR-CLUSTERS AND METEORIC SWARMS.

31. The hydrogen will rob the heavy molecules of their energy : hence in any considerable graze the heavy metals might not indefinitely expand. They would lose their velocity by radiation and by doing work against gravitation, and they would be attracted back again, and may form a star in the centre of the nebula. Some nebulæ have such stars.

32. In a partial impact the coalesced part will not have all its motion converted into heat. The momentum on the two sides will not be exactly balanced. The body will consequently tend to spin. It is generic of partial impact that it tends to cause rotation in all the bodies

produced, and also that the rotation is all in the same direction.

33. It is a peculiarity of oxygen that it tends to render its compounds with metals less volatile than are the metals themselves. Almost all metallic oxides are less volatile than the metals forming them. Consequently, when metallic atoms and oxygen come together, they produce molecules that tend to coalesce. Thus nuclei form in a nebula and it becomes dusty. If the nebula be rotating this dust tends to move in orbits, and it would be constantly picking up other dust and molecules. Thus a rotating metallic nebula, in which molecular selective escape has dissipated the light molecules, tends to aggregate, not necessarily into a single body, but oftener into a number of bodies orbitally connected. If the mass be large it will become a star-cluster, if small a meteoric swarm.

34. In star-clusters,impacts should be frequent. These groups should be photographically observed to notice any sudden increase of intensity. Then the pair of impacting stars should be watched for nebulæ and for variability.

35. Star-clusters would as a rule be very deficient in helium and neon, and also have but

little uncombined hydrogen and not a large quantity of hydrogen in any condition, otherwise it would, except under special circumstances, have become a single star. But partial impact would make gas of the heavier elements and dissipate such gas. This would produce resistance and cause other impacts; thus variable stars may characterize some star-clusters, or special parts of a star-cluster, as is the case.

COMETS.

36. Meteoric swarms when near the sun would be distorted, and the constituent fragments would impact with extraordinary frequency. They would therefore become very brilliant, and show as comets. The friction would produce an enormous development of heat and electricity.

37. It is certain that the material of a tail of a comet does not belong to the comet itself. It is the dust of space lit up in some way like motes in air illuminated by a search-light. The phenomenon of the tail is almost certainly electrical. In a paper " On a New Relation between Heat and Electricity," I have discussed agencies that may explain the phenomenon.

38. Such a swarm, when close to the sun, would have its near part drawn in advance of, and its distant part left in the rear of, the general swarm. Its weak attractive power would often cause it to separate into a train.

The above are some of the phenomena that may ensue in the coalesced mass.

VARIABLE STARS.

39. The two stars that grazed would have a part cut out of each : this would expose the probably hot interior. Each star would entangle a portion of the other. This would increase the temperature and luminosity of the cut part of each.

40. The stars after collision would recover their sphericity chiefly by the molten interior welling up. This by momentum would overfill the space, and there would be a rhythmic tidal action, the molten lake overfilling and then sinking.

41. The retardation of the sheared stars by the entangled material would cause them to spin. This would act chiefly on the outer layers ; the inside would tend to retain the original rotation of the star.

42. Thus in the sheared stars there are three tendencies struggling with one another—(1) the original rotation, (2) the new rotation, (3) the tidal action.

43. But the new rotation would be a large component. We have therefore a star which rotates and shows us alternately its hot and cool sides. The old rotation and the tidal motion produce other fluctuations of intensity, and also inequalities of the rate of motion.

44. Evidently such a body as described would be a variable star, and for a time such stars would be in pairs.

45. Many variable stars are in pairs. It is so striking a phenomenon that the probability is one hundred sextillions to one against its being the result of chance.

46. The stars of these pairs would have a motion directed outward from each other. The spectra might show displaced lines, if so the displacement should be in opposite directions in the two stars.

47. Conduction, convection, tidal motion, and the contending rotations will tend to bring about equality of temperature. This condition of variability will consequently be a temporary

one. The star will ultimately become of uniform luminosity. These characteristics are all of them known peculiarities of variable stars.

48. Convection is due to difference of density. This difference may result from differences of temperature, or of chemical composition or of both. The lake of fire in the sheared star will consist of heavier molecules than the remaining surface, and it will also be at a higher temperature. These two will tend to neutralize each other; so that equality of temperature due to convection will not be brought about quickly.

49. Therefore, although such variable stars will doubtlessly become uniform, it is surprising what a number of agencies there are tending to retain this inequality of temperature. On theoretical grounds it appears that this condition of unequal heating may, as an extreme case, last thousands of years.

DOUBLE STARS.

50. The work of cutting the stars will be infinitesimal in relation to their available energy before collision. It will not cause any appreciable lessening of the velocity of the escaping stars. But the middle body will exert a power-

ful attraction. It will exercise a retarding influence, preventing the retreat of the two bodies, equal to that of three times the mass either body loses. Hence, when two equal bodies lose a third of each by impact, the attraction acting on each of the escaping bodies is doubled. Therefore they do not as a rule become free from the new central body unless the original proper motion were large.

51. If however, the original proper motion were large, and the graze small, the two stars would escape each other. If the original motion were small, and the graze, on an average, more than a tenth, then the two stars would become orbitally connected.

52. Such a pair, when thus connected, would form a permanent double star. It is the opinion of some astronomers that impacting stars becoming orbitally connected could not make double stars, as they think such stars would impact again. But they overlook the fact that the nebula that retarded their escape and formed an important factor after the first impact, will have dissipated before they return.

53. Hence the eccentricity will lessen greatly, and, as a rule, instead of impacting again they

will be scores of millions of miles away at perihelion. In fact, they may have about the eccentricity that double stars are known to have.

54. There is a possibility of a second impact when the graze has been a very small fraction, or if one of the stars were multiple. But the period of the subsequent recurrence of impacts, after the first recurrence, would lessen in point of time. On calculating the dates of the apparently recurrent star, "The Pilgrim," viz., 945, 1264, and 1572, this is proved to be the case. The dark bodies producing these impacts must be of absolutely stupendous dimensions. The dark bodies producing Nova Aurigæ were probably 8,000 and 4,000 times the mass of the sun respectively.

55. Double stars should be more often variable than single stars. Struve has proved that they are hundreds of thousands of times more variable than ordinary stars.

56. We should expect them also to be more frequently coloured. This, too, is most strikingly the case.

57. We should look for them to be associated with nebulæ. Herschel says the association of

nebulæ and double stars is most truly remarkable.

58. They should be highly eccentric. This is also well known to be the case.

59. A large number of agencies tend to render the orbit less eccentric. These are fully discussed in my papers of 1880.

NEBULÆ.

60. If stars come into partial impact, the tendency to form nebulæ of definite form, other than planetary or cometic, seems to be entirely destroyed by the outrush of the high-velocity gas. This is not the case with the impact of nebulæ.

61. Impact may take place between nebulæ, between star-clusters, between meteoric swarms, and between any two similar or dissimilar celestial bodies. The graze may be little or large; the original bodies may have had a small or great proper motion; and all these peculiarities will tend to vary the results.

62. If two nebulæ come into a slight grazing impact there will result a double nebula, which will show a spindle at the centre. As they are parting company they may have temporarily a dumb-bell appearance; but, as the two sides of

the coalesced nebula are moving in opposite directions, a spiral begins to form at the centre of the spindle. As the ends travel on in space the spiral would increase, and ultimately a double spiral would result.

63. One or both of the original nebulæ may be entangled in the spiral.

64. If the impact be considerable, the two nebulæ do not escape each other, and an annular nebula results. It would have gauze-like masses of nebulæ at the poles of the ring, produced by the outrush of gas during the impact.

65. There are nebulæ corresponding to every one of these conditions: nebulæ coming into impact—some in impact with the spindle showing between them; there are also spindle nebulæ left alone; others with an incipient spiral visible at the centre; others where the spiral is more distinctly visible; and others where the double spiral is fully developed.

66. Finally there are annular nebulæ with the gauze-like caps referred to above. Thus at one and the same time the evolution of nebulæ at any of its stages may be watched, and not unlikely older drawings may show the less advanced stages of the same nebulæ.

THE ORIGIN OF THE GALACTIC UNIVERSE.

67. If two Cosmic systems such as the Magellanic Clouds come into grazing impact, an annular cosmic system will result, the poles of which will be covered with nebulous matter owing to the outrush of gas during the millions of years of the impact.

68. This principle of outrush needs some explanation. As two globular masses close in upon each other, the motion will lie chiefly in a plane which might be called the orbital plane. It is obvious that the pressure of the heated gas resulting from the impact, as the bodies close the gas in, can find no escape in this orbital plane, but can only escape upwards and downwards.

69. Stars will pass into such caps of nebula as originally covered the galactic poles, and will there be entrapped, and will attract nebulous matter. They will thus become nebulous stars ; or they may be volatilized altogether and become globular nebulæ. Such a distribution of nebulæ exactly corresponds with our universe.

70. Where globular nebulæ are thick we should expect double, spindle, and spiral nebulæ. These nebulæ are actually found amongst the

nebulæ at the polar caps of the Milky Way. Again, where stars are thick we should expect planetary nebulæ, double, temporary, and variable stars, and star-clusters—all the result of the impact of stars. These, as the theory requires, are almost entirely found within the Milky Way.

71. If the universe were formed by such a graze as we describe we should expect a greater density of stars in those parts of space where their motion chiefly directs the two original cosmic systems. Proctor speaks of two such clustering masses as striking features of our universe.

72. If our galactic system were the result of impact there would be much community of motion in adjacent stars. This is a remarkable peculiarity of the stars in the Milky Way. A large number of further coincidences are debated in my papers "On the Visible Universe," in the N.Z. Phil. transactions, and in the body of the present volume.

THE SOLAR SYSTEM.

73. Nebulæ must tend to entrap bodies passing through them. Such bodies would frequently become orbitally connected with the

nebula. Then, when the nebula, with these bodies, became a sun, it would produce a system with planets in all azimuths, in the same way as the comets that our solar system has entrapped are in all azimuths.

74. Were a sun to impact with such a body or with a dense star-cluster, and were the graze considerable, all the planets would be whirled roughly into one plane, and the central mass would become a bun-shaped nebula.

75. It is not improbable that our sun was formed by an incipient star-cluster impacting with a nebulous sun, and that the present solar system constitutes a large part of the whole impacting mass. In other words, it is probable that there was not a large ratio of the original bodies dissipated into space during the impact, but it is probable that the impact was a large-ratio collision.

76. It is to be supposed that in every impact much matter will leave the system. Some of the gas extruded by the pressure acting along the axis will be lost, with much of the hydrogen. The attraction, therefore, on the return of the planets may be so much lessened by these losses that the orbits may be converted into an

approximation to a circle. The nebula would expand enormously; all the matter of it that might pass outside aphelion distance would not aid in attracting the planet back. Perihelion distance would thus be increased by this agency.

77. Of course, at first the rotation on their axes of the newly-constituted planets would be in all possible directions. Thus, the axes may be in the ecliptic, or the motion may be retrograde. The order observed in the rotation of the inner planets will be established afterwards, the outer planets largely escaping these agencies.

78. Gaseous adhesion and many other agencies are at work to cause apsides to rotate. Consequently the larger nebular planets would gradually pick up all matter within the limits of their orbits, thus giving the rough order to the distance of the planets that is commonly known as Bode's Law.

79. In a rotary nebula I have shown that much matter will tend to become meteoric. The absorption by a planet of every meteorite will tend to cause the planet to rotate in the common direction of the nebula, and will cause

the axis to tend to become upright on the axial plane. This action will tell most with planets near the centre of the series, such as Jupiter and Saturn, because they will be largely gaseous and in the thick of the meteoric matter. The outer planets will necessarily be almost beyond the region of such influence, while the near ones will have but slight entrapping atmospheres, as explained hereafter.

80. All this exactly accords with the actual inclinations of the axes of the respective planets.

81. It is probable that the orbits of the planets were originally much smaller; but much of the potential energy of dimension would, as they shrank, be converted into energy of rotation, and this, by tidal action, into increased distance from the sun. The same may also be true of the moons.

82. As the volume of the nebula diminished its temperature would increase. An increased temperature would produce molecular exchanges between the planets and the nebula, and this would most affect the nearer bodies. Thus the near planets would lose all their light atoms by their escape into the surrounding nebula; whilst, on the other hand, the low velocity of the heavy

molecules of the nebula would allow these molecules to be picked up by the planets.

83. Hence the near or inner planets would be small and dense, as we find them in our solar system, and the outer planets large and less dense, as in reality they are.

84. The heat of the contracting nebula will tend to increase the temperature of the planets, which would consequently expand. This would lessen their hold upon their light matter in two ways: (1) by the lessened attraction produced by expansion, and (2) by the increased velocity of the molecules themselves. The near planets would consequently be composed almost wholly of the heavy metals. The smaller and hotter any planets were, the greater would be their chance of being without atmosphere. The absence of this and the small volume of the planets would lessen their trapping action. Consequently they would not be so upright in their orbital planes as the middle planets.

85. The distant planets, being almost out of the nebula, would not collect an appreciable quantity of matter; hence the original axes of rotation may be at any angle, or even retrograde, as, in fact, they are.

86. As the nebula shrank within the orbits of the planets, the planets would again pick up light molecules that would form an atmosphere; but the temperature of the planets would not allow of much hydrogen being picked up unless it were in combination.

87. The resistance and contraction of the central nebula would clear space of all meteoric dust unless such were orbitally connected with a planet. The asteroids are probably parts of an exploded planet. The impact of a rapidly-moving body plunging into a planet could easily blow it to pieces. It has been suggested that, if so, such bodies would pass through the common point of their explosion. This idea is an error, as a planetary perturbation and other agencies would prevent such coincidence.

88. The trapping of their moons by the planets would probably occur when the planets were nebulous, and before the central nebula had attained to any great density. Hence they would lie roughly on the planet's equatorial plane.

89. Whilst a body of the mass of the earth could pick up an atmosphere, the smaller attractive power of the moon would not allow

this at the temperature it would be at when its nebula contracted within its orbit. The moon would probably be much nearer the earth at first, but the stopping of its rotation by tidal action would increase the distance.

90. Many other agencies that would convert the system under discussion into one similar to our own are treated of in my paper on "Causes tending to alter the Eccentricity of Planetary Orbits," in N. Z. Phil. Trans.

MATHEMATICAL CONDITIONS OF THE FORMATION OF NEBULÆ.

91. It can be shown, that if two gaseous suns impact completely, the suns having had no original proper motion, and that were the whole of the motion converted into heat, and this heat into the potential energy of expansion, then the new sun would have a diameter the sum of the diameters of the original suns. It can also be shown that such a condition is one of molecular equilibrium.

92. Consequently the complete impact of two gaseous suns not possessing much original motion, and brought together by gravitation, does not make a nebula of them; but as soon as

the paroxysm of the encounter is over they are of the same temperature as before, having used up all their energy in increasing to the sum of their original diameters. This is a remarkable and unexpected result.

93. Were there great original proper motion, they might become a nebula by complete impact; but were the original velocity of the two bodies very high, and the impact of very great energy, then an indefinitely-diffused nebula would result. Such a nebula, if hot, would be unstable, and would indefinitely expand. Croll's theory to account in this way for an increase in the age of the sun's heat is therefore untenable.

THE COSMOS POSSIBLY IMMORTAL.

94. If our universe be proved, from its configuration and character, to have been formed of two previously-existing cosmic systems as appear probable from *et seqq.*, then the entire cosmos may be made up of an infinity of cosmic systems.

95. Meteoric swarms prove space to be dusty with wandering dark bodies, and "molecular selective escape" proves it also to be spread with

countless myriads of molecules of light gas. It is probably due to the dust of space that we see no distant cosmic system other than the Magellanic Clouds.

96. If this be the case, radiation must all be caught by the dust of space, and, unless some agency be found to take this heat away, the dust must be gradually increasing in temperature.

97. Bodies not in closed orbits when moving at high velocities take but a short time to pass over great distances; they take longer and longer periods as the velocity is reduced. Hence the molecules of hydrogen and other light gases when they have travelled into positions comparatively free from the influence of matter, will be generally moving slowly. But such slowly-moving molecules are cold: hence such gas may be at a lower temperature than any other matter in space.

98. Whenever by their mutual motions such molecules strike cosmic dust, they will acquire the temperature of the latter: that is, they will increase their molecular velocity. They will thus have a new start of motion.

99. It is evident that unless it strikes something the molecule can only lose this motion by

radiation and by doing work. When it has done work, it will be further from matter, or in a position of higher potential, and Crookes' experiments prove that molecules do not radiate in free paths except immediately after encounters.

100. Moving matter not in orbits will tend to move slowest where there is least matter—that is, where gravitation potential is highest—because in these places it has done most work against gravitation. Where bodies moving indiscriminately move slowest they obviously tend to aggregate: in other words the hydrogen and other light gases of space tend to accumulate in the sparsest portions of space.

101. Thus radiant energy falls upon the dust of space and heats it. This heat gives motion to molecules, and the molecules then tend to use their new energy to pass to positions of high potential, thus converting low-temperature heat—that is, dissipated energy—into potential energy of gravition—that is, into the highest form of available energy.

102. This action will tend to go on until attraction is equal in different parts of space. Thus we should have, if there were no counter-

acting influence, in one part of space bodies in mass, in another part diffused light gases.

103. But long before this equality of distribution can ensue another action is set up. The mass of light gas will become a retarding trap to indiscriminately-moving bodies.

104. Free bodies moving indiscriminately will tend to pass through a group of masses similar to our galactic system, through which 1830 Groombridge is passing now. But they will tend to be trapped in any mass of gas they encounter. Thus the place that was most void of matter now begins to have more than a regular distribution of matter. A new cosmic system of the first order has begun to form.

105. The potential of this part of space lessens, and the work required to reach these positions not being so great as at first, oxygen and other heavier molecules get there, increasing the density; and oxygen also tends to produce non-volatile compound molecules. Hydrogen would form water molecules, these would coalesce; but helium and the other cosmic pioneers do not combine, they remain permanently gaseous.

106. Although dense bodies sent out of

cosmic systems by the interaction of three bodies would generally pass through old cosmic systems where matter is in dense masses, they evidently would not pass through such vast gaseous aggregations as the incipient cosmic systems. The bodies would be retarded by the friction produced, and perchance volatilized, forming nuclei in the general mass; their mutual attraction would cause denser aggregations to occur, and a cosmic system of the first order would be produced.

107. Two such systems colliding produce a system of the second order. The Magellanic Clouds are probably systems of the second order. This is suggested by their spiral form.

108. Such systems colliding with any other cosmic system, produces a system of the third order. Our own galactic system is very probably a tertiary system. It is too orderly to be a primary system and too irregular to be a secondary system.

109. When three bodies pass near each other, one at least has its velocity increased. In this way it is possible to account for the enormous velocity of 1830 Groombridge, although this high velocity might also be due to the attraction

of our universe, or of a near dead sun. The truth of which latter idea could be ascertained by observations of its regularity of speed. Whenever the velocity is great enough to enable the body to escape the attraction of the universe, the body is lost to it, and the other two bodies would be moving more slowly. If this should occur only once in a thousand cases—seeing that when it does occur the body escapes—given time enough, much of the energy of any individual system must thus be used up in allowing the escape of bodies.

110. If it could be shown that the impact of two similar universes would result in the formation of one which, in a similar stage, was of larger mass than the larger of the originals, then impact would be, on the whole, an aggregating agency, and the permanent equilibrium of the cosmos would be disturbed.

111. This is probably not the case, for during the impact of the universes themselves much matter would escape, and at every impact of individual bodies within the new universe light molecules would be set wandering that would ultimately leave the system. When the new system has become more dense, during the

approach of any three bodies one would occasionally be sent out of the system. There are other agencies that, together with these, render it possible for two similar cosmic systems, by coalescing to become one, which, when contracted to the size of either of its components retains no more matter than one of the original systems.

112. We have in these phenomena a complex series of agencies tending to overcome the dissipation of energy and the aggregation of matter. Impact developes heat, separates bodies, and diffuses gas. Radiation falls on the matter of space and heats it: this energy is taken up by the hydrogen to increase its velocity. As the hydrogen loses this new velocity it is carried to positions of higher potential. It will tend to linger in the empty parts of space, and it then becomes a trap for wandering bodies. These wandering bodies are separated from systems by the mutual interaction of three bodies.

113. Thus, is suggested the possibility of an immortal Cosmos, in which we have neither evidence of a beginning nor promise of an end. The sequence of these agencies is as follows:—

(*a*) Diffusion of heat by radiation.

(*b*) This radiation, falling on the dust of space, heats it.

(*c*) The heat of this cosmic dust is taken away by slowly moving light molecules having their velocity increased.

d) Free molecules are also sent out of systems by partial impacts, by selective molecular escape, and other agencies.

(*e*) Free molecules will remain longest in the position of maximum potential where their motion is least, and will consequently tend to aggregate in the empty parts of space.

(*f*) By the interaction of three bodies the velocity acquired by one sometimes takes it out of the cosmic system.

(*g*) Hydrogen and the cosmic pioneers then become a trap for wandering bodies that tend to be stopped and converted into dense nebulæ.

(*h*) These dense nebulæ tend to attract surrounding gas; they cool and shrink, some ultimately forming solid bodies.

(*i*) These bodies, by mutual attraction, give density to the new cosmic system.

(*j*) Such systems are of the first order.

(*k*) The impact of systems of the first order produces systems of the second order.

(*l*) Any other impacts produce systems of the third order, of which our galactic system is a type.

(*m*) The coalesence of two cosmic systems does not necessarily, as a final result, produce a system of a larger mass than one of the two original systems from which it was formed, as many agencies are tending to send matter out of the coalesced mass.

(*n*) It is thus seen that dissipation of energy is but a part of a complex cyclical process; and there is consequently the possibility of an immortal cosmos in which we have neither evidence of a beginning nor promise of an end, the present being but a phase of an eternal rhythm.

The diagrammatic scheme of cosmic evolution illustrates these agencies (page 198). It must be noted that bodies and systems are printed in italic capitals; and where several such are one above another it implies sequence of phenomena.

The following Papers on Constructive Collision are to be found in the Transactions of the N.Z. Institute.

ON TEMPORARY AND VARIABLE STARS. July 4th, 1878.

ON PARTIAL IMPACT, &c. August 1st, 1878.

ON THE VISIBLE UNIVERSE. February 13th, 1878.

ON THE GENERAL PROBLEM OF STELLAR COLLISION. March 13th, 1879.

PRESIDENTAL ADDRESS ON THE GENESIS OF WORLDS AND SYSTEMS. April 3rd, 1879.

CAUSES TENDING TO ALTER ECCENTRICITY OF PLANETARY ORBITS. May 6th, 1880.

ON THE ORIGIN OF THE SOLAR SYSTEM, August 5th, 1880.

THE ORIGIN OF DOUBLE STARS. August 5th, 1880.

SOME RECENT EVIDENCE IN FAVOUR OF IMPACT. November 1st, 1893.

THE IMMORTALITY OF THE COSMOS. November 7th, 1894.

SYNOPTIC STATEMENT OF THE PRINCIPLES AND PHENOMENA OF COSMIC IMPACT. Prepared for the criticism of Scientific Men and Societies. November 7th, 1894.

INDEX

Absolute Zero, 23
Aggregative High Potential, 203, 223; media of, 204
Algol, 166; a dead sun, 38; variable, 50
Alpha Centauri (nearest fixed star), 162
Anderson (Mr.) and Nova Aurigæ, 37
Andromeda, nebula of, 188
Annular Nebulæ, see Nebulæ
Anthelm's Variable (Nova Vulpeculæ), 58, 227
Aphelion, attraction at, 73
Apsides, 256
Arcturus, 207
Argon, 83
Argus (Eta), 64
Asteroids, see Planetoids
Astronomical measurements, 161
Astro-physics, 15
Atmosphere, of incipient planets, 137; oxygen and hydrogen in, 23; temperature, 23
Atomic Theory (Dalton's), 80; see also Atoms, Elements and Molecules
Atomic Weights, 81; importance of, 14; and dissipation of gas, 96; and Selective Molecular Escape, 87-8
Atoms, Clark Maxwell on, 86; complexity of, 12, 17; fixed and indestructible, 84; movement of, 18; particles smaller than, 83; size of, 17; spectra, 54
Attraction, see Gravitation
Aurora Borealis, 125, 142
Axial Escape, 131, 221; extrusion, 190; fundamental thought of, 215
Axis, planetary, 120-1

Ball (Sir Robt.), on Impact, 66; dead suns, 38, 166; Mars, 107; Selective Molecular Escape, 107; speed of stars, 67
Barnard (Prof. E. C.), measures Nova Aurigæ, 37, 59
Beverly (Mr.), 56
Binaries, see Double Stars
Birth of Suns, 44
Bode's Law, 119, 136
Bradford Daily Argus, quoted, 194
Cailletet, 18
Canes Venatici, 188
Cassiopeia (Mu), 207
Ceres, 119
Celestial phenomena, 10; celebates, 83
Centaur, 162
Centrifugal Force, 134
Centripetal Force, 134
Cetus, 49
Chaos and symmetry, 138
Charts, Proctor's, 172; Newcomen's, 172; Waters', 172
Chemical Elements, 81; composition and impact, 80
Chlorine, 89
Clausius, 201
Clusters, 101 seq.; see also Star Clusters
Coalesence, 29, 69; and comets, 149; and Solar System, 129; conditions of after impact, 39; energy involved, 71; of nebulæ, 72; of suns, 130; of suns cannot produce nebulæ, 177; whirling and clusters, 110; see also Impact
Cohesion, 19
Combustion, 206
Cometic Nebulæ, 183
Comets, 126, 149, 251; formed by collision, 149; luminosity of, 152; masses of gravitating meteors, 150; not of small mass, 152; path of, 155; perturbations within, 150; produced in different ways, 149; retardation of, 77; tails due to electrical induction, 154
Composition, chemical and velocity, 42
Compounds, volatile, 89
Condensation, 19; of clusters, 115; of planetary nebulæ, 98
Conduction, 60; slow in liquids, 61
Constructive Impact, see Impact
Constructive Power of the Theory, 79
Convection, 60
Corona (Solar), and zodiacal light, 142; bat's wing form, 143; cause of, 142

COSMIC DUST, formation of, 89; and zodiacal light, 125.
COSMIC EVOLUTION, 192-4, 259; a cyclic process, 210; agent of, 179; and accepted principles, 84; and monotomic elements, (pioneers), 83; and oxygen, 89; and velocity of molecules, 86; diagram, 198; see also COSMIC SYSTEMS
COSMIC PIONEERS, 83, 206; function of, 204-6; see also ARGON, CRYPTON, HELIUM, NEON, XENON
COSMIC SYSTEMS, growth of, 207, 229; Mr. Russell's photographs, 192; of first order, 204-5; see also COSMIC EVOLUTION and MAGELLANIC CLOUDS
COSMOS, immortal, 13, 199, 210, 267; infinite, 79; possibilities of, 116
COUNTERPARTS of stars and nebulæ, 184
CRITICAL VELOCITY, 25; and temperature, 36; of Earth, 25, 108; of planetoids, 109; of Sun, 26
CROLL'S theory untenable, 267
CROOKES' experiments, 14; tubes, 16
CROWN, new star in, 33
CRYPTON, 83
CRYSTALISATION, 19
CYCLES, cosmic, 210
CYCLONES on the sun, 117
CYGNI, (61), 93; see also SWAN

DALTON'S atomic theory, 80, 83
DARWIN, (Prof. G. H.), on the Moon, 124
DARWINISM, 211
DATES of Temporary Stars, 32, 33, 36, 58
DAYS, length of, 121
DEAD SUNS, collision of, 105; demonstated in Algol, 38; Dr. Johnstone Stoney on, 38; move faster, 72; pre-existent, 175; Sir Robert Ball on, 38
DEMON STAR, see ALGOL
DENSITY, a factor of variability, 61; of planets, 119; of planets explained; 13
DIRECT IMPACT impossible, 28; see also IMPACT
DISSIPATION, and atomic weights, 96; of matter and energy, 95; of meteors, 130; of temporary stars, 45; of Third Body, 30
DISSIPATION of ENERGY, 200; overcoming, 86; theory confuted, 195
DOUBLE ROTATION of sun, 118; of variables, 63
DOUBLE SPIRAL NEBULÆ, see NEBULÆ
DOUBLE STARS, (Chapter iv.) 65, 254; and nebulæ, 75; caused by gravitation, 68, 78; characteristics, 74; eccentric orbits, 71, 73; entrapping action, 114; formed by a tangential approach, 77; Herschel on, 75; in clusters, 114; nearly all in the Milky Way, 77; numerous, 69; Proctor on, 70; orbits produced by interaction, 77; revolution of, 69; Sir Robert Ball on, 68; within nebulæ, 76; see also DOUBLE VARIABLE STARS, IMPACT, and VARIABLE STARS
DOUBLE VARIABLE STARS, 51; Mr. J. E. Gore's records, 75; Struve's observations, 75
DUPLICATION of orbits after impact, 72
DUST, formation of cosmic, 89
DUST SWARM, formation of, 110; velocity of, 125
DUSTINESS of space, 202
DYNAMICAL THEORY OF GASES, 14, 84; and Nebular Hypothesis, 128; pressure and temperature, 85

EARTH, as a planet, 119; critical velocity of, 25, 108; eclipses, 122; "Romance of the," 139; size of, 11; size of orbit, 161; velocity of, 25
ECCENTRIC orbits explained, 132
ECLIPSES of the moon, 122; of the sun, 122, 142
ELASTICITY, 21
ELECTRICITY and comets, 152-3; and ether, 84; escape of, 153-4; negative, of the sun, 153-4
EL DORADO, a scientific, 65
ELEMENTS, 81; energy of, 96; oxengenation of, 110; volatile, 89; see also NEW ELEMENTS
ENERGY, absorption of, 156; and matter, respective dissipation of, 95; and velocity, 40; associated with matter, 20; available for shearing, 39, 69; converted, on moon, 124; dissipation of, 200; heat, a form of, 20; indestructibility of, 20, 200; involved in impact, 27, 71; motion of mass converted, 22; of coalescence, 71; of elements, 96; on moons, 136; transmutation of, 20, 142; of Sun, 118
ENTRAPPING of molecules, 207
EPHEMERIDES of variable stars, 56

Escape of electricity, 154; of gases, (see Selective Molecular Escape and Axial Escape)
Eta Argus, 64
Eternity's Pendulum, 116
Ether and comets' tails, 156; and electricity, 20, 84
Evolution, a universal law, 13; (cosmic), agent of, 179; diagram. 198; of life, 139; of Milky Way, 174; of planetary life, 116; of planets, 116; of clusters, 103; of systems, 207
Explosion of planets, 144

Fluorescence, 17
Force, see Energy

Galactic Poles. 13, 167, 180
Galaxy, see Milky Way
Gases, compound, 85; compressible, 85; dynamical theory, 14, 84; entrapping power, 207; expand into nebula, 51; invisible masses, 176; monatomic, 14, 85; motion of, 85, 107; nature of, 107; pressure and temperature, 85; retarding effects of, 113; sorting of, 88
Gasification after impact, 87
Geological agency, 124, 139
Glacial periods, 139
Globular Nebulæ (Chapter xii.), 180; see also Nebulæ
Gore (Mr. J. E.) on double variables. 75; list of do., 56
Gravitation, and double stars, 68; between two centres, 137; increases force of impact, 38; irregularities of, 183; media of, 203; velocity of, 40, 71
Grazing Impact, see Impact
Great Bear, 92
Groombridge (1830), 43, 72, 86, 115, 206

Harvest Moon, 122
Heat, a form of energy, 20; a mode of motion, 15; and motion of mass, 15; conduction, 60; convection, 60; degrees of, 22; evolved by impact, 67, 87, 105; of gases, 16; of liquids, 16; of solids, 16; of temporary stars, 34; of two kinds, 15, 16; radiation after impact, 61; see also Temperature and Thermometer
Helium, 83; dissipation, of, 96; velocity of, 87
Herschel (Sir J.) on shape of universe, 171
Herschel (Sir Wm.), drawings of nebulæ, 186: on nebulæ, 184; on nebulæ in relation to stars, 76; on planetary nebulæ, 92, 165; on double stars and nebulæ, 75
Hind, on the galaxy, 172
Hind's variable (T Tauri), 59
Humboldt quoted, 103
Hydrogen, cosmic function of, 204; dissipation of, 96; liquifaction of, 18, 22; motion of, 68, 95; peroxide, 81; velocity of, 87; weight of, 81
Hypothesis of Impact, 34

Immortality of the Cosmos, (Chapter xiii), 13, 199, 210, 267
Impact (Chapter i), 10, 240; accounts for Nova Aurigæ, 55; advice to students, 235; agencies of, 130; agent of cosmic evolution, 179; "a master key" 179; and chemical composition, 80; and evolution of universe, 169, 174-5; and gaseous suns, 42; and gasification, 87; and gravitation, 38; author a solitary worker, 190; causes variable stars, 51, 56, 60; comprehensiveness of the theory, 13, 79; demonstration of, 216; diffuses gas, 149; energy involved, 27, 39; formation of double stars, 72; formation of Jupiter, 135; formation of solar system, 129; formation of temporary stars, 38; formation of planetary nebulae, 51, 94; fundamental thought of, 106, 214; grazing, 34; growing belief in, 66; heat evolved by, 67, 87, 105; hypothesis of, 34; in clusters, 112, 116; list of papers. 276; mathematics of, 42, 177; of dead suns, 105; of nebulæ, 182, 186, 189; other theories insufficient, 35; partial, 28; possibility of, 27, 66; pressure of gas after collision, 191; Proctor's views, 70; produces comets, 149; produces nebulæ, 30, 105; producing three bodies, 28, 51; question by Humboldt, 163; recurrent, rare, 70, 256; result of, 41, 66; shearing energy, 69; simplicity of theory, 14; temperature of, 24; velocity considered, 22, 24, 51, 71, 87; will not transform gaseous suns into a nebula, 43; see also Coalescence, Partial Impact, Third Body, and Variable Stars

INDESTRUCTIBILITY of energy, 200; of matter, 199
INDUCTION causes comets' tails, 154

JOULE, 199
JULES VERNE, 44
JUNO, 119
JUPITER, 119; and comets, 77; and perturbation, 146; formation of, 135; Proctor on, 135

KELVIN (Lord), on dissipation of energy, 200
KEPLER'S temporary star, 32
KINEMATICS, 181
Knowledge, quoted, 75

LAKE OF FIRE, 62; tidal action, 63
LAPLACE'S NEBULAR HYPOTHESIS, 120; reasons against, 128
LAVOISIER, 199
LEO, 168, 188
LICK OBSERVATORY, 37
LIFE on planets, 116
LIGHT, analysis, 52; from travelling bodies, 54; Struve's conclusion, 156; see also SPECTRUM ANALYSIS
LOCKYER, meteoric hypothesis of, 128

MAGELLANIC CLOUDS, 192, 209; Mr. Russell's photographs, 192
MAGNETIC STORM, 125, 142
MATHEMATICS of impact, 42, 177, 267
MATTER, an indestructible entity, 20, 199; constitution of, 17; and energy, respective dissipation of, 95
MARS, 119; Sir Robert Ball on, 107
MAXWELL (CLARK), on atoms, 86
Melbourne Argus quoted, 66
MERCURY, 119
MESSIER'S 64th nebula, 76
METALLIC rain, 62
METEORIC HYPOTHESES, 128
METEORIC PHENOMENA (Chapter x.), 140, 249; comets, 149, 251; planetoids, 144; Saturn's rings, 147; solar corona, 142; zodiacal light, 140
METEORS, 153; dissipation of, 130; trains derived from comets, 151; visible and invisible, 126, 150
MINOR PLANETS, see PLANETOIDS
MILKY WAY, 165; cloven disc theory, 168; composition of, 167; disposition of components, 171; evolution of, 13, 174; nebulæ in, 182; not a primitive system, 208; Proctor on, 171; profusion of double stars, 77; see also GALACTIC POLES
MIRA (the "Wonderful" Star), 49, 112, 165; period of, 49
MOON, a member of the solar system, 124; harvest, 122; potential energy, 124; Prof. G. H. Darwin on, 124; tidal action and rotation, 122-4; see also SOLAR SYSTEM
MOONS, and potential energy, 136; entrapping of, 137; explosion of, 148; of planets, 122; orbits of, 145; origin of, 135; revolution of, 122; see also PLANETS
MOLECULAR ESCAPE and Cosmic Evolution, 94; see also SELECTIVE MOLECULAR ESCAPE
MOLECULES, at low temperatures, 18; equal velocities, 113; frangibility of, 82; free, 82; heat after impact, 87; motion of gas, 107; travel radially, 88; two kinds of, 82; velocity and temperature, 22; escape of, see SELECTIVE MOLECULAR ESCAPE
MONATOMIC MOLECULES, 83, see also NEW ELEMENTS
MU CASSIOPEIÆ, 207
MULTIPLE NEBULÆ, see NEBULÆ

NEBULÆ (Chapter xii.), 180, 257; action of, in coalescence, 72; and cosmic dust, 90; and double stars, 75; Andromeda, 188; advice to students, 191, 235; at Galactic Poles, 167; beauty of, 101; cannot be produced by coalescence of suns, 177; cometic, 183; comparison of drawings, 191; double nebulæ, 184; double spiral, 181; Dr. Roberts' investigations, 188; entrapping power, 127, 137; expansion of solar, 134; formed by coalescence, 70; (galactic), pre-existent, 174; globular, 180; Herschel on, 75, 184, 186; in relation to stars, 76; in the Milky Way, 182; impacts between, 182, 186; kinds of, 167; Lord Rosse on, 188; Messier's 64th, 76: meteoric theory of, 189: multiple, 181; Nova Aurigæ, 59; of solar system, 131; physical connection, 184; photographs of, 188; (polar) Proctor on, 176; pressure after collision, 191; prevent recurrent impact, 72; produced by impact, 30; retardation by, 78; rings, 181, 189; size of, 185; spindle, 181;

spiral, 181, 187: structure of, 189; symmetry of, 180; see also Planetary Nebulæ
Nebular Hypothesis, 120; confuted, 128
Nebulosity of variable stars, 59
Neon, 83
Neptune, 119, 131; circular orbit of, 131; orbit of, and size of planetary nebulæ, 93
New Body formed by Impact see Impact, Temporary Stars and Third Body
Newcomen's "Astronomy," 168: charts, 172
New Elements, 83; see also Argon, Crypton, Helium, Neon, Xenon
New Stars, see Temporary Stars
New Zealand Philosophical Society, 70, 276
Nitrogen in planetary nebulæ, 90
Nova Aurigæ, 36, 232; accounted for by impact, 55; disc measured, 37; expands into planetary nebula, 59; mass of, 105; motion of constituents, 54; Mr. Anderson discovers, 37; Mr. Taylor on, 37; size of, 164; spectrum, 37, 54; sudden appearance, 59; third body demonstrated, 37, 54
Nova Vulpeculæ, 227; a variable star near it, 58
Nubeculæ, see Magellanic Clouds

Olbers on origin of planetoids, 144
Orbits, circular, 135, 148; eccentricity of, 71; enlargement of, 72, 138; hyperbolic, 73; of comets, 155; of double stars, 71, 78; of earth, 161; of moons, 135; of planets, how formed, 133; of planetoids, 145
Orion, 165
Oxygenation, 109, within planetary nebulæ, 98
Oxygen, energy of, 95; in cosmic evolution, 89; motion of, 86; weight of, 81
Ozone, 82

Pairs of variable stars, 56, 57
Pallas, 119; discovered by Olbers, 144
Partial Impact, 28; see also Impact
Peek (Sir C. E.) on variable star irregularities, 63; variable star notes, 59
Pegasus, 188
Perturbation of Jupiter, 146: of planetoids, 145; within comets, 150
Philosopher's Wool, 89
Philosophical Magazine, 153
Philosophy and science, 13
Photographic Annual, 188
Pictet, 18
Pilgrim, temporary star, (1572), 32; recurrent, 256
Planetary Nebulæ (Chapter vi), 91, 245; age of, 99; and nitrogen, 98; and Selective Molecular Escape, 91; clusters and stars within, 92; composition of, 98; condensation, 98; formed by impact, 45, 51; hollow shells of gases, 93-4; in Nova Aurigæ, 37; persistent, 97; size of, 93, 97; transitory, 98; see also Nebulæ
Planetoids, acceleration of motion, 145; critical velocity of, 109; discovered by Olbers, 144; formed by explosion, 136; intersection of orbits improbable, 147; not originally meteoric, 144; number of, 119; orbits of, 145
Planets, atmosphere of, 137; Bode's Law, 119; characteristics of, 129; circular orbits of, 135; days, 121; density, 135; distances increased by tidal action, 124; explosion of, 144; groups of, 119; inner, dense, 119; moons, 122; motion of, 119; nebulous, 137; outer, large, 119; orbits of, 133; orbits, eccentricity of, 71; orbits increased, 138; result from impact of pre-existent systems, 116, 129; revolution of, 120, 127; rotation, 120; seasons, 121; years, 120; see also Solar System
Poles of the Milky Way, 180
Proctor, charts of, 172; meteoric hypothesis of, 128; on double stars, 70; on impact, 70; on Jupiter, 135; on polar nebulæ, 176; on probability, 172; on star drift, 168; on the galaxy, 171; on the universe, 173
Projectiles, power of, 20, 40

Radiation in Crookes' tubes, 16
Radiometer, 202
Raleigh (Lord), and monatomic gases, 14
Ramsay (Prof. W.), and monatomic gases, 14
Rankine, 201

Records of temporary stars, 32
Religion of Science, 211
Retardation due to gas, 113
Ring Nebulæ, see Nebulæ
Roberts (Dr. Isaac),on nebulæ.188
"Romance of the Earth," 139
Röngten Rays, 17
Rosse (Lord), sketch of spiral nebula, 187
Royal Astronomical Society, 188
Royal Dublin Society, 107
Rotation, and tidal action, 135; double, 63; of planets, 120; of sun, 117; of temporary stars, 43; of variable stars, 51
Russell (Mr. H. C.), on Magellanic Clouds, 192

Satellites, see Moons
Saturn, 119
Saturn's Rings, beauty of, 101; an exploded moon, 136, 148; meteoric bodies, 136; order in, 143; not originally meteoric, 144; not pre-nebulous, 136
Schmidt, on the galaxy, 172
Science and philosophy, 13; specialisation of, 104; religion of, 211
Seasons, 121
Selective Molecular Escape (Chapter v.), 80, 87, 247; and compound bodies, 97; and planetary nebulæ, 91; fundamental thought of, 215, of hydrogen, 97; Sir R. Ball on, 107
Solar System (Chapter vii.), 117, 260; deduced from impact, 127; evolution of, 132; expansion of nebula, 134; its order and irregularity, 13, 128, 136; original nebula, 131; origin of (Chapter ix.), 127; planets, 129, theories of, 13; true members of, 124; results from impact, 125; see also Sun, Planets, Planetoids and Moons
Southern Cross (cluster), 102
Space, dustiness of, 202; imperfectly filled, 170
Spectrum Analysis, 52, atomic motion, 54; New Star in The Crown, 33; Nova Aurigæ, 37; of double variable stars, 75; of temporary stars, 33, 41, 52; of travelling bodies, 54
Spencer (Mr. Herbert), 201
Spheres, formation of nebulous, 183
Spindle nebulæ, see Nebulæ
Spiral nebulæ at Galactic Poles, 182; see also Nebulæ
Spring tides, 123
Stability of Third Body, 29
Stars, movement of, 162; nearest, 162; quadruple, 166; related to nebulæ of regular form, 76; size of, 164; speed of, 67; triple, 166; variability and motion, 57; within planetary nebulæ, 92; see also Stellar Phenomena
Star-Drift, 168, 175
Star Clusters (Chapter vii), 101, 249; and variable stars, 112; beauty and colours of, 101, 103; cessation of impacts, 113; condensation of, 115; double stars within, 114; evolution of, 103, 110; evolution of planets, 116; future of, 115; impacts within, 103, 112, 116; number and size of components, 102, 112; perturbation within, 110; Southern Cross, 102; Toucan, 102; within planetary nebulæ, 92
Stellar Phenomena, dimensions, 164; evolution, 13; movements, 162; velocities, 207; weddings, 70; see also Stars
Stoney (Dr. G. Johnstone), 107; on dead suns, 38
Struve, on absorption of light, 156; on double variables, 75; list of stars, 171
Sun, composition of, 105; corona of, 142; critical velocity of, 26; cyclonic spots, 117; direction of movement, 118; double rotation, 118; eclipse of, 142; electrical phenomena, 125; energy of, 118; flashes on, 125; negatively electrified, 153; pre-existent conditions, 125; result of fused and coalesced bodies, 129; size of, 117; sunspots, 117; sunspots and zodiacal light, 142; rotation, 117; velocity of, 25, 118; see also Solar System
Suns, brilliancy of, 72; coloured, 103; impact of gaseous, 42; velocity of, 40; see also Dead Suns
Swan, New Star in, 33
Synoptic Statement, 240 seq

Taylor (Mr. Alfred), and Nova Aurigæ, 37
Temperature, and critical velocity, 36; atmospheric, 23; equalisation of, 60; freezing point, 22; high, 24; molecular motion, 18; molecular velocity, 22; of impact, 24; of Third Body, 29; pressure of gases, 85; see also Heat

TEMPORARY STARS, (Chapter ii.) 31, 245; at stellar distance, 32; ancient and modern, 32; brilliancy and disappearance, 32; composed of luminous gas and incandescent solids, 33; dissipation of, 45; formed by impact, 38; gasification, 43; heat of, 34; in Cassiopeia (1572), 31; in The Crown (1866), 33; in The Swan (1877), 33; Nova Aurigæ (1891), 36; Nova Vulpeculæ (1670), 58; phenomena of, 34; seen by Kepler, 32; spectra, 33, 41, 52; sudden appearance of, 31; summaries of observations, 52; recurrent, 256; rotation, 43; theories of, 35; within a cluster, 103
THERMO-DYNAMICS, 13; laws of, 219
THERMOMETER, 23; zero, 22
THIRD BODY, 69; becomes a nebula, 30; characteristics of, 41; dissipation of, 30, 94; expansion of, 43; formation of, 39, 43; in Nova Aurigæ, 37, 54; produced by impact, 29; stability of, 29; temperature of, 29; retarding effects of, 45; rotates, 51; when very small, 106; see also IMPACT and TEMPORARY STARS
THOMPSON (Prof. J. J.) on particles smaller than atoms, 83
TIDAL ACTION, 38; and heat, 123; and rotation, 135; and rotation of moon, 122; on planetary distances, 124; on variable stars, 63
TIDAL WAVES, 123
TIDES, spring, 123
TOUCAN, The (cluster), 102
TRANSMUTATION, of energy, 105; of matter and energy, 109
TRIGONOMETRY, 160
TRIPLE STARS, 166
T TAURI, (Hind's variable), 59; nebulosity of, 59
TYCHO BRAHE, 31

UNIVERSE, THE VISIBLE (Chapter xi.), 159, 259; evolution of, 13; Proctor on, 173; produced by impact, 169; see also GALACTIC POLES and MILKY WAY
URANUS, 119
URSÆ MAJORIS, 92

VARIABLE STARS (Chapter iv.), 49, 252; Algol, 38, 50; Anthelm's star (Nova Vulpeculæ), 58; associated with nebulosity, 59; atmospheric disturbance on, 62; closely associated, 56; density, 61; diminish in intensity, 62; double, 75; double rotation, 63; double within a nebula, 51; eccentric, 63; ephemerides, 56; equalisation of temperature, 60; explained by impact, 51; factors of variability, 60; formation of, 111; Hind's variable, 59; in clusters, 111; irregularities explained, 63; lakes of fire on, 62; long periods and nebulosity, 59; loss of variability, 60, 62; Mira (The "Wonderful"), 49; molten interior, 50; Mr. J. E. Gore's list of, 56; near Nova Vulpeculæ, 58; permanency of, 57; produced in pairs, 55; relative movement of pairs, 57; rotation of, 51; sides unequally illuminated, 50; Sir C. E. Peek's notes, 59; Sir C. E. Peek's observations of irregularities, 63; three sources of light, 63; T Tauri, 59; see also DOUBLE STARS
VELOCITY, 22; and chemical composition, 42; and energy, 40; and gravitation, 71; and retardation, 45; at impact, 24; critical, 25; fixed for different molecules and temperatures, 22; independent of composition, 21; loss after impact, 71; of cosmic bodies, 35; of dust swarms, 125; of Earth, 25; of impacted bodies, 51; of molecules after impact, 87; of Nova Aurigæ, 37; of stars, 207; of small suns, 40; of Sun, 25; on approach of three bodies, 78; overcomes gravitation, 40; see also CRITICAL VELOCITY
VELVETY STAR explained, 99
VENUS, 119; beauty of, 101; transit of, 161
VERNE (JULES), 44
VESTA, 119; discovered by Olbers, 144
VIRGO, 188
VOGEL, 163
VOLATILITY of elements and compounds, 89

WATER, composition of, 81; dissipation of molecules, 95
WATERS (Mr. SYDNEY), charts of, 172
WEDDINGS, stellar, 70
WEIGHTS, atomic, 14
WHALE (The), 49
WHIRLING COALESCENCE, see COALESCENCE

WONDER STAR, 110; see also MIRA

XENON, 83
X-RAYS, see RÖNGTEN RAYS

YEARS, planetary, 120

ZERO, see THERMOMETER

ZINC, oxide, 89
ZODIACAL LIGHT, 124; a mass of meteors, 125; a meteoric swarm, 140; and solar corona, 142; and sun spots, 142; brilliant, 142; due to small bodies, 140; equatorial position, 141; nature of, 140; part of original solar nebula, 140

THE END

W. Jolly & Sons, Printers, Aberdeen.